Arnold Schwarzenegger
Governor

DG Interconnection Monitoring: The FOCUS-II Project

Forging a Consensus on Utility System Interconnection

Final Report

PIER FINAL PROJECT REPORT

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California Energy Commission
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Power Measurement, Ltd, provided the monitoring systems, installed the monitors, and provided technical support.

We acknowledge and appreciate the entities who agreed to allow us to monitor their DG systems that enabled this report.

PREFACE

The California Energy Commission's **Public Interest Energy Research (PIER) Program** supports energy research, development and demonstration (RD&D) projects that will help improve the quality of life in California by bringing environmentally safe, affordable and reliable energy services and products to the marketplace.

The PIER Program annually awards up to $62 million to conduct the most promising public interest energy research by partnering with Research, Development, and Demonstration (RD&D) organizations, including individuals, businesses, utilities, and public or private research institutions.

PIER funding efforts are focused on the following RD&D program areas:

- Buildings End-Use Energy Efficiency
- Energy Innovations Small Grant Program
- Energy-Related Environmental Research
- Energy Systems Integration
- Environmentally-Preferred Advanced Generation
- Industrial/Agricultural/Water End-Use Energy Efficiency
- Renewable Energy Technologies

What follows is the final report for Contract #500-00-013, conducted by Reflective Energies and Overdomain, LLC. The report is entitled "Making Better Connections: Cost Effectiveness Report on Interconnection of Distributed Generation in California Under the Revised Rule 21". This project contributes to the Energy Systems Integration.

For more information on the PIER Program, please visit the Energy Commission's Web site at: http://energy.ca.gov/research/index.html or contact the Energy Commission's Publications Unit at 916-654-5200.

ABSTRACT

This study assessed the impact of commercially installed Distributed Generators (DG) to the California electric distribution system (grid). It is the first such monitoring performed anywhere. While the initial sample was small (11 DGs at 6 sites), the DG systems chosen were based on diversity and complexity. Monitoring was performed using PM's ION 7600 instruments, measuring voltage and current over 15,000 times per second for each installation. The results were compared against earlier benchmark surveys conducted by EPRI and SCE that assessed the power quality on utility distribution lines (without DG). Power Quality parameters measured include voltage sags and swells, harmonics and flicker. Over two years of data (cumulatively over 230,000 hours) have been collected to date. Power quality at the DG systems was generally better than that of the benchmark surveys. There were no events of the DG impacting the distribution system, and the only event where the distribution system impacted DG was caused by a lightning strike. The DG systems used did not export power to the distribution system. The study is being expanded to cover more complex systems that are evolving, such as multiple DGs, DGs connected to electrical networks, microgrids, multiple tariffs and export of power to the distribution system. Monitors at two more sites (5 DGs) are currently being installed. Several more are planned in future. Existing sites will continue to be monitored.

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ACRONYMS

ac	alternating current
ASD	adjustable speed drive
CBEMA	Computer Business Equipment Manufacturers Association
CHP	combine heat & power
CT	current transformer
dc	direct current
DG	Distributed Generation
DIC	diesel internal combustion
DPQ	distribution power quality
EI	Edison International
EPRI	Electric Power Research Institute
FC	fuel cell
FFT	Fast Fourier Transform
Hz	Hertz
IEEE	Institute of Electrical and Electronics Engineers
ITIC	Information Technology Industry Council
kA	kilo-amperes (1000 amperes)
kV	kilo-volts (1000 volts)
kVA	kilo-volt-ampere (1000 amps)
kVAR	kilo-var (1000 var)
kW	kilo-watts (1000 watts)
kWh	kilo-watt hour (1000 watt hours)
LADWP	Los Angeles Department of Water & Power
MCT	methane combustion turbine
MIC	methane internal combustion
mK	mega-watts (1000000 watts)
MMT	methane microturbine
NGCT	natural gas combustion turbine
NGFC	natural gas fuel cell
NGIC	natural gas internal combustion
NGMT	natural gas microturbine
PC	personal computer
PCC	point of common coupling
PG&E	Pacific Gas & Electric
PLC	programmable logic controller
PQ	power quality
PT	potential transformer
pu	per unit
PV	photovoltaic
RMS	root mean square
SARFI	System Average RMS Variation Frequency Index
SCE	Southern California Edison
SDG&E	San Diego Gas & Electric
SFPUC	San Francisco Public Utility Commission
SEMI	Semiconductor Industry Council
SMUD	Sacramento Municipal Utility District
TDD	total demand distortion
THD	total harmonic distortion
UPS	uninterruptible power supply
VAR	unit of reactive power (reactive volt-ampere

EXECUTIVE SUMMARY

Introduction

Distributed Generation ("DG") is becoming more commonplace, especially in California. This report presents the results of monitoring commercially installed DG for its impact on the grid and vice versa. This is the first time such a study has been undertaken anywhere. The study represents a small sample, a total of eleven generators at six locations. Monitors for two additional sites with five generators are being installed. Several more sites are in the concept stage for installation in the future. Monitoring was done for two years beginning in mid-2002 and covers over 230,000 hours of data logged.

The data was compared to previous distribution line power quality studies by EPRI and SCE.

Overview of the DG Monitoring Project

This monitoring project is part of a larger project known as FOCUS-Interconnection II (FOCUS II) that supports the California Energy Commission with streamlining the process of interconnection of distributed generation (DG) in California. The means used to measure impact was to measure power quality at the DG-customer interface (the "Point of Common Coupling" or "PCC") of the distribution system and at the DG itself. The most modern Power Quality metering was used, capable of capturing waveforms at 256 samples per cycle (over 15,000 measurements per sec). Power quality parameters measured included voltage sags and swells, frequency, wave form, harmonic distortion, flicker and other transients.

The monitoring to date showed that so far, for the sites selected, there is very little impact of DG on the distribution system. Similarly, the impact of the distribution system on the DG has been minimal. From the results, it appears that the process used for review and approval of DG in California is reasonable, perhaps conservative. If the current processes for review increasing penetrations of DG are unlikely to create challenges because the current growth rate of DG is slow, while experience with DG is growing more rapidly.

Additional Data Needed

It is imperative that significantly more data be collected on the impact of DG on the system. A follow-up study will increase the number of sites monitored. It is hoped that similar studies will be undertaken by others in California and elsewhere. The cumulative conclusions of the data will help characterize the impact of DG and provide intelligence to help lower the cost of interconnection while increasing reliability.

Background

Distributed Generation in California has made progress in recent years, but still faces obstacles to widespread adoption. The California Energy Commission working with the CPUC has championed DG and has set in place revised rules that significantly streamline the DG interconnection approval process. As progress continues towards orderly and simplified requirements for interconnection, stakeholder groups have expressed concern about the impact

DG would create. It would be valuable to monitor the DG projects implemented under the Revised Rule 21 to assess the impact of DG on the grid. Utility engineers are intentionally conservative, charged with the sanctity of the grid, and therefore averse to trying new technologies. Utility engineers are intentionally conservative since per **PUC §330 (f)** "*The delivery of electricity over transmission and distribution systems is currently regulated, and will continue to be regulated to ensure system safety, reliability…, (g) Reliable electric service is of utmost importance to the safety, health and welfare of the state's citizenry and economy…*" and **§451** "*Every public utility shall furnish and maintain such adequate, efficient, just, and reasonable service, …equipment and facilities… as are necessary to promote the safety, health, comfort and convenience of its patrons, employees, and the public.*"

Contractual Requirements

The contract language that set up the monitoring program is shown below:

> **Task 2.2 Select and Monitor twelve (12) DG projects**
>
> The purpose of this task is to improve the cost-effectiveness of DG interconnection while maintaining the safety and reliability of the grid. This will be accomplished by gaining precise technical feedback on what effect interconnecting DG has on the local distribution grid. The FOCUS team will provide data, analysis and recommendations to the Energy Commission for its use and for the Interconnection Workgroup.
>
> The Contractor shall:
>
> 1. Develop Guidelines for selection of DG projects to be monitored. Guidelines shall include items such as providing a balance between DG technologies, Interconnection technologies, technical complexity such as feeder voltage and configuration, cooperativeness of participants, location, and estimated cost of monitoring. The Contractor will attempt to include at least one project with each electric investor-owned utility and one municipal utility, if available. If this diversity is not available, the Contractor will notify the Commission Contract Manager and the two will resolve the matter.
>
> 2. Submit the Guidelines to the Commission Contract manager for review at least 10 working days in advance of the Critical Project Review. These Guidelines shall form the basis of discussion at the Critical Project Review meeting.

Monitoring Program Steps

The monitoring program required the following steps:

1. Select twelve (12) monitoring sites, which provide a balance between DG technologies, interconnection technologies and technical complexity.
2. Select a monitoring instrumentation system.
3. Develop a Test Plan.

4. Install instrumentation at these sites, which takes measurements of the impact of the interconnection by the generator upon the distribution/transmission grid.
5. Monitor the instrumentation and create a database for analysis of the data.
6. Analyze the data, provide significant results to the Interconnection Workgroup and provide a final report.

All the above steps are complete. Steps 1 and 2 were accomplished by creating a document titled "DG Monitoring Guidelines" included as Appendix F. Step 3, the Test Plan is included as Appendix G. Steps 4 & 5 are complete while this report completes step 6.

Project Implementation – Issued Faced

A detailed search and selection process was used to find the best power quality monitoring instrumentation. This effort resulted in selection of Power Measurements Ltd. to provide and install the instruments.

It was decided to select the most complex DG systems interconnected to points on the distribution system that were as diverse as possible. However, in order to select a site, the Utility customer and DG owner had to give their consent, and this was not always easy. When developing the DG Monitoring Program, a lot of uncertainties about the utilities, location, customer type, DG installation planning, etc., made this a challenging task. The Redlands site is a prime example. When the monitors were installed prior to installation of the microturbines it was originally anticipated that about one to two months of baseline data would be colleted prior to installation of the microturbines. Due to issues with the medical facility permitting, AQMD coordination and application process, the microturbines installation was delayed over one year.

In order to assess the impact of the DG on the grid and vice versa, it was decided to place monitors at the PCC and at the DG itself based on Rule 21 Working Group comments to the DG Guidelines[1] and Monitoring Test Plan[2]. This increased the cost, but provided significantly greater insight into the impact.

A central system for monitoring all the DG was needed. It was decided to install modems, coupled to DSL phone lines, cable or other means to transmit the data to the home base.

Data collection proved to be a major challenge. Systems were not always compatible, and several changes to providers or data systems were necessary.

Data analysis was performed using Power Measurement software, however, several adaptations were required in order to make the software functional, and additional analysis was necessary.

Another challenge faced was that several DG hosts or developers experienced internal delays or problems with their DG systems. One host experienced over a year's delay. Another system was taken out of service for several months.

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[1] See Appendix F for DG Monitoring Guide.
[2] See Appendix G for Monitoring Test Plan.

The total DG systems monitored included two fuel cells, five microturbines, four Photovoltaic system, and three IC engines. All systems were on radial feeders, except for two on network systems. At each selected customer site, a monitor was installed and connected to the electrical system at the service entrance (known as the "Point of Common Coupling" or "PCC. An additional monitor was installed at the DG. The monitors obtain steady state and transient event data.

Only one of the systems, a fuel cell, exported power. Small amounts of power were exported daily, with the fuel cell running steady-state while house load was fluctuating with time-of-day. One PV system was on a Net Metering tariff, but did not export any power.

The data collected covered 11 DG systems at 6 sites, for one to two years, with data received at about one-thousandth of a second interval while triggered events captured waveforms at 256 samples per cycle. It was a major challenge to massage and evaluate this enormous volume of information.

Website

A website was established that displayed real time data on the sites being monitored. The website is www.dgmonitors.com which includes summary data and a link to the real time data (www.dgmonitors.com/ion).

Conclusions

The following conclusions may be made for the data analyzed from the DG Monitoring project from mid 2002 through October 2004:

- The critical point to measure impact on the grid is the PCC. Power quality at the PCC was very good when compared to the Power Quality benchmarks established by EPRI and SCE. One measure of power quality is SARFI event rates. The average PCC monitor logged an average of 13.93 "$SARFI_{90}$"voltage sags and interruption (voltage drops below 90% of rated voltage) events per year[3] which is far lower than the 54 events per year in the EPRI distribution system power quality study and 47 events per year in the SCE study.

- Power Quality at the DG itself was also very good. The average DG monitor at the DG experienced averaged about 11.20 SARFI90 events per year. This was less than half the event rate at the PCC. This indicates that the DG is not impacting power quality problems into the distribution system. It also indicates that the distribution system is having no negative effects on the DG.

- $SARFI_{50}$ measures larger events (voltage dips over 50% of rated voltage). $SARFI_{50}$ events at the PCC were less than one per year, compared to 5 per year in the SCE study and 12 per year in the EPRI study.

[3] See Section 2.4 for more on voltage sag.

- The one system that exported power did not show any increased impact on the grid resulting from the export. There are several PV systems exporting small amounts of power with no known consequences. There may be room to allow some export of power in future. Export will be given a priority for selection of sites in future.

- None of the other power quality factors, such as flicker and harmonics were of concern.

- The only distribution event, which caused a Fuel Cell trip, was a lighting strike in late October 2003 at the Los Angeles site. The strike destroyed a Silicon Controlled Rectifier in the inverter and caused the only remaining operating DG (NGMT3) to enter a constant transient condition until the Fuel Cell was isolated and the NGMT3 reset. The anti-islanding scheme worked successfully and the system was repaired and restored. No other anti-islanding trigger events occurred.

- The power quality monitors themselves had an average availability over 99% despite several problems with the PCC monitor with cause loss of communications.

- No voltage swells of any consequence were encountered during the entire monitoring program.

- Overall, the monitoring showed that for the sites monitored, during the monitoring period, the DG had no impact on the grid, and with one exception, the grid had no impact on the DG. This provides some comfort that the DG installations to date are being performed conservatively.

- Some DG is delayed for long periods for reasons unrelated to interconnection. Many DG give preference to their main businesses needs, and this gives DG a low priority. The rise in natural gas prices made natural gas DG less attractive, deferring many projects.

1 Overview of DG Monitoring System

1.1 The Monitoring Project

1.1.1 Objective

The objective of the FOCUS-II Monitoring Project is to "characterize the electrical effects of DG on the distribution system"[4]. The purpose of this project is to assess the impact, if any, of interconnected DG on the distribution system or distribution system on DG. At each selected customer site, a monitor is installed and connected to the electrical system at the service entrance or PCC. One additional monitor is installed to monitor the DG. Both monitors collect steady state and transient event data.

The current system consists of 11 generators at six locations. Monitors for two more sites with five generators are being installed. Monitors were installed at the PCC and at the generators themselves. The data collected from the PCC is compared with data collected from the DG monitors, or vice versa. These comparisons are used for identifying problem areas. In addition, the data collected is used for assessing the impact of different power quality events.

1.1.2 Design Concept

At each customer site, a monitor is installed at the PCC and also at the DG. These two monitors together allow determination of which power quality problems originate on distribution system and which can be attributed to the DG. A total of 15 monitors were operating between August 26, 2002 and October 31, 2004 which is the date range of the data for which this report is written. Four monitors at the San Diego (Inductive)and San Francisco sites were in the planning and construction phase. After considerable negotiation with the utility and customer, an installation scheme was developed where the PCC monitor was installed on the customer side of the main feeder disconnect or breaker. This design basically provided monitoring at the same point as the utility meter for the site but did not effect the utilities meter installation.

The data collected by the power quality monitors in the field is transmitted to Reflective Energies master web server via the Internet. One computer allocated for the project is dedicated to downloading data from the power quality monitors in real time. Data is stored on a multi-gigabyte hard drive and backed up on an Iomega remote hard drive. The data is accessed at the master computer directly or via the intranet by accessing the website (dgmonitors.com).

The monitor chosen for the project was the ION 7600 or ION 8500 High Visibility Energy and Power Quality Meter manufactured by Power Measurement, Ltd., a company headquartered in Victoria, British Columbia, Canada. The monitor collects both triggered and sampled measurements from four voltage and four current channels. Triggered measurements provide the transient data while the sampled data provides the steady state data required to benchmark the DG/Distribution interface.

[4] Contract Number 500-00-013 Exhibit A, Technical and Economic Performance Objectives, page 1.

FIGURE 1-1: ION 7600 & ION 8500

	
ION 7600	***ION 8500***

The ION 7600 and ION 8500 summarize power quality measurements into simple pass/fail indicators when used with ION Enterprise Software. Monitor compliance with international standards such as EN50160, IEC 61000-4-7 (harmonics) , and IEC 61000-4-15 (flicker) . Or configure the unit for IEEE Std. 519-1992, IEEE Std. 1159-1995 and SEMI F47.

1.1.3 Basis for Selection of Sites and Systems

The sites were selected to be representative of utility, DG technology and customer diversity. The FOCUS II monitoring project specifications require that it "include at least one project with each electric investor-owned utility and one municipal utility, if available". Additionally, the FOCUS II project required that the monitoring program "include items such as a balance between DG technologies, interconnection technologies, technical complexity … and estimated cost of monitoring."

1.1.4 Sites Included & Locations

The site selection was developed as part of the Monitoring Program Guidelines.

1.1.4.1 Utilities/Municipalities Sites Selected for Monitoring

The site selection was based on the size in MW of the Utility/Municipality customer load. Based on that process, Table 1-1 summarizes the sites selected.

TABLE 1-1: UTILITY/MUNICIPALITY SITE DISTRIBUTION

Site Distribution	**Active or Operational**		**Plan or Under Construction**	
Utility/Municipalities	**No. of Sites**	**No. of DG**	**No. of Sites**	**No. of DG**
LADWP	1	4		
PG&E	1	1		
SCE	3	4		
SDG&E	1	2	1	2
SFPUC			1	3
Total	**6**	**11**	**2**	**5**

1.1.4.2 DG Technology Distribution

The technology selection was based on the types of DG for which applications were being made. These applications were summarized by the Utilities/Municipality and presented at the Rule 21 Working Group meetings. Based on that process, Table 1-2 summarizes the sites selected for the monitoring program.

TABLE 1-2: FOCUS MONITORING SITES BY TECHNOLOGY AND UTILITY

DG Technology Distribution			
DG Technology	**No. of Sites**	**Utility/ Municipality**	**Status**
Fuel Cell (abbreviated FC)	**1**	LADWP (1)[5]	Survey 6/12/02 Survey 2/25/03 Install 03/26/03 & 4/23/03 Operational 6/23/03
	1	SCE (1)	Survey 6/27/02 Install 9/8/02 Operational 9/8/02
Natural Gas Internal Combustion Engines (abbreviated NGIC or IC)	**1**	PG&E (1)	Survey 7/30/02 PCC Installed11/14/02 NGIC Installed4/28/03 Operational 4/29/03
Synchronous	**1**	SDG&E (2)	Survey 8/13/02, Install 1/20/03 Operational 2/11/03
Inductive	**1**	SDG&E (2)	Survey 10/11/04, Install – Pending, Operational - Pending
Microturbine (abbreviated MT or NGMT)	**1**	LADWP (1) [5]	Survey 6/12/02 & 2/25/03 Install 03/26/03 & 4/23/03 Operational 6/23/03
	1	SCE (1)	Survey 7/02/02 Install 8/26/02 MGMT installation Startup 9/22/04 Forecast Operational December 2004
Photovoltaic (abbreviated PV)	**1**	SCE (1)	Survey 7/08/02 Install 9/10/02 Operational 9/10/02
	1	SFPUC (3) [6]	Survey 6/14/04 Install – Pending Operational - Pending

[5] LADWP – One site with two technologies (FC & NGMT)
[6] SFPUC – One site with three PV Systems
[7]PG&E – One site with two technologies (NGIC & PV)

1.1.4.3 *Site Locations & Details*

TABLE 1-3: CUSTOMER TYPE DISTRIBUTION

Customer Type					
DG Technology (Utility/Municipality)	**Location**	**Size (kW)**	**Technology**	**IC Type**	**OP Mode**
Commercial Building					
LADWP	Los Angeles	120 300	NGMT (Capstone 2-C30 & 1-C60) FC (Fuel Cell Energy 1-DFC 300)	P	PS
SCE	Irvine	200	FC (UTC 1-PC25)	P	PS
SDG&E	San Diego (Synchronous)	400	NGIC (Hess 2-200 Microgen)	P	PS/Cogen
SDG&E	San Diego[8] (Inductive)	400	NGIC (Hess 2-200 Microgen)	P	PS/Cogen
Convenience Store					
SCE	South Gate	14	PV (BP HI Performance Thin Film PV)	P	PS
Convention Center					
SFPUC	San Francisco[8]	676	Power Light Solar Electric System (Sanyo HI Efficiency Dual Ply PV Modules 244 kW, 225 kW & 207 kW)	P	PS
Manufacturing Facility					
PG&E	Sunnyvale	3000	NGIC (Waukesha - 16VAT27GL)	P	PS
Medical Facility					
SCE	Redlands	120	NGMT (Capstone 2-C60)	P	PS/Cogen

Technology Key: NGMT = Natural Gas Microturbine, NGIC = Natural Gas Internal Combustion, PV = Photovoltaic,
Interconnection (I/C) Type Key: P = Parallel, MP = Momentary Parallel, I = Isolated

Operating (OP) Mode Key: Cogen = Cogeneration, PS = Peak Shaving

1.1.5 Instrumentation Used

After an extensive evaluation process, the Power Measurement ION 7600™ and ION 8500™ were selected.[9] The details of this selection process are documented in the Monitoring Test Plan (Attachment B). These monitors are a high visibility energy and power quality compliance meter. Used at key distribution points and sensitive loads such as the DG, they offer unmatched value, functionality, and ease of use. These monitors were selected based on their expanded power quality analysis features along with transient waveform capture, sampling rate, harmonics analysis, and memory.

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[8] Site in the planning stage or under construction as of 11/15/04

[9] For more information, visit the ION 7600 product page at http://www.pwrm.com/Products/meters/7600.asp or the ION 8500 product page at http://www.pwrm.com/products/ION8500/

When the meter is integrated with Power Measurements ION Enterprise™ software (http://www.pwrm.com/products/ionenterprise/) or other energy management and Supervisory Control and Data Acquisition (SCADA) system, the hardware/software package provides multiple communication channels and protocols for graphical presentation of the data and man-machine interface.

FIGURE 1-2: IRVINE MONITORS INSTALLATION

1.1.6 Computing Infrastructure

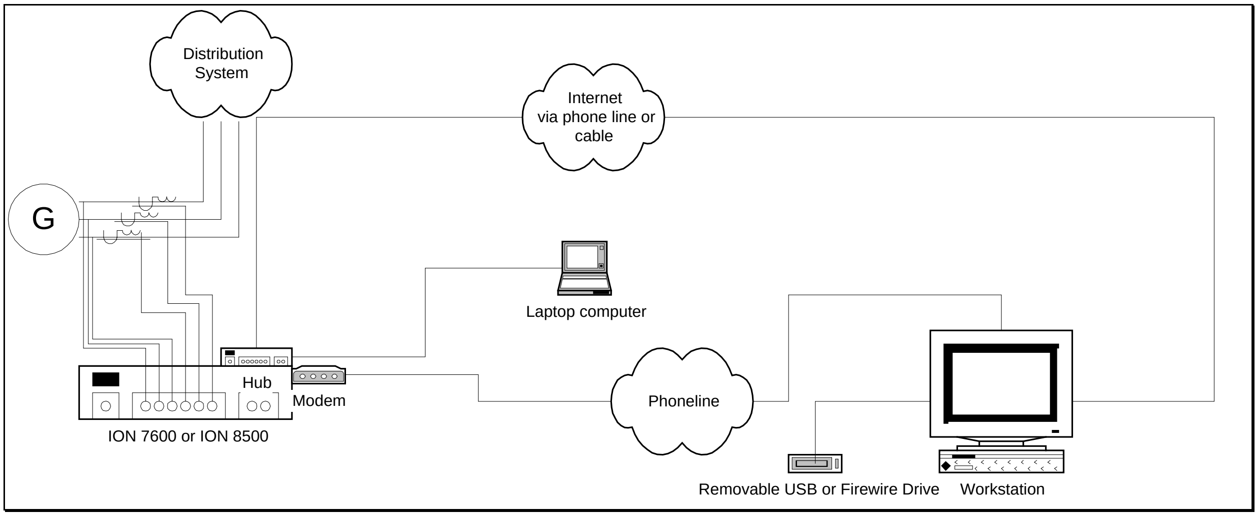
1.1.6.1 Server Workstation

A single computer (**Dell Precision™ Workstations 530)** is dedicated to the monitoring system, as illustrated in Figure 1-3. This is a 1.7 GHz Dual Pentium IV CPU computer configured with Microsoft Windows XP Professional and 1.5 GB of memory with two internal hard drives (40GB & 120GB) plus two external hard drives (120GB & 240GB). It is capable of downloading measurements from the all monitors in the field on a continuous basis. It can interface with each site to monitor status and view data and then use for reporting. This workstation downloads the data from the ION 7600 and ION 8500 while also at the same time hosting the website (dgmonitors.com). The database that is generated by this process is also used for report creation, data reduction and analysis.

1.1.6.2 Time Synchronization & Timekeeping

The ION 7600 & 8500 utilizes the following Time Synchronization & Timekeeping scheme. Time synchronization lets us synchronize the internal clocks of ALL networked monitors and devices. Once synchronized, all data logs have timestamps that are relative to a uniform time base. This allows us to achieve precise sequence-of-events and power quality analyses. To synchronize clocks, the **ION software**, an NTP server, broadcast time signals across the network every 3600 seconds. NTP can synchronize all monitor clocks within our Ethernet network. The server uses **Atomic Time Synchronizer** utility to keep its PC clock accurate. It periodically (every 60 seconds) checks and synchronizes the server clock with NIST atomic time servers and act as a time server for our Ethernet network of monitors.

FIGURE 1-3 FOCUS-II COMPUTING INFRASTRUCTURE



For this project, a domain name (dgmonitors.com) was obtained and a web site was developed. The website consists of two parts:

1. Program overview and status, and
2. Access to real time data from the monitors using Power Measurement's ION Enterprise Software Version 4.5[10].

[10] For more information, visit the ION Enterprise Software product page http://www.pwrm.com/products/IONEnterprise.features/.

FIGURE 1-4: WEBSITE AT DGMONITORS.COM

CEC DG Interconnection Monitoring Program

Home | Site Map

Focus II Home

Home

Site Info

Documentation

Program Purpose

The purpose of the FOCUS - Interconnection II (**FOCUS II**) Monitoring Program is the support of the California Energy Commission (**CEC**) during the development of Rule 21 and to streamline the interconnection process for the installation of Distributed Generation (DG) in California. Within that overall goal, Task 2.2 is a program of monitoring, data collection and analysis, and reporting for selected Distributed Generation (DG) systems chosen for diversity related to generation, grid and customer impact concerns. Through this task, information is collected and used to assist the Interconnection Workgroup and others in understanding the impacts of interconnection of DG on the electrical grid.

Monitoring Program Mission

The Monitoring Program has seven DG sites with nineteen monitors. For each site monitored, the test program installed a Power Measurement monitoring system. The monitor chosen for the project was the ION 7600 or ION 8500 which are a High Visibility Energy and Power Quality Monitor. The monitor collects both triggered and sampled measurements for four voltage and four current channels.

These monitors comes with an extensive selection of pre-configured data screens and measurements so it can be use right out of the box, or customize the meter to fit particular site requirements. When the meter is integrated with Power Measurements ION Enterprise™ software or other energy management and Supervisory Control And Data Acquisition (**SCADA**) system, the hardware/software package provides multiple communication channels and protocols for graphical presentation of the data and man-machine interface.

ION 7600 | *ION 8500*

Typical installation of the monitors at the Redlands site is shown in the following figure.

Power Measurement

A single computer (**Dell Precision™ Workstations 530**) is dedicated to the monitoring system. This is a 1.7 GHz Duel Pentium IV CPU computer configured with Microsoft Windows 2000 Professional and 1.5 GB of memory. It is capable of downloading measurements from the all monitors in the field on continuous bases. It can interface with each site to monitor status and view data as well as use for reporting. This workstation downloads the data from the ION 7600 and ION 8500 at the same time hosting the website (**dgmonitors.com**). The database that is generated by this process is also used for report creation, data reduction and analysis.

Real Time Data

Access to real time data is via **ION WebReach**. **WebReach** can be used to access meter displays from the convenience of a web browser. Reflective Energies has created screens and they are displayed by your web browser, including real-time numeric data, background graphics or diagrams, and views of event, data and waveform logs.

Hyperlink to real time data from monitors (See** Figure 1-5**)

Contact Information

You are visitor: Hit Counter

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Electronic mail

FIGURE 1-5: ION ENTERPRISE WEBREACH & MAIN SCREEN FOR ALL SITES[11]

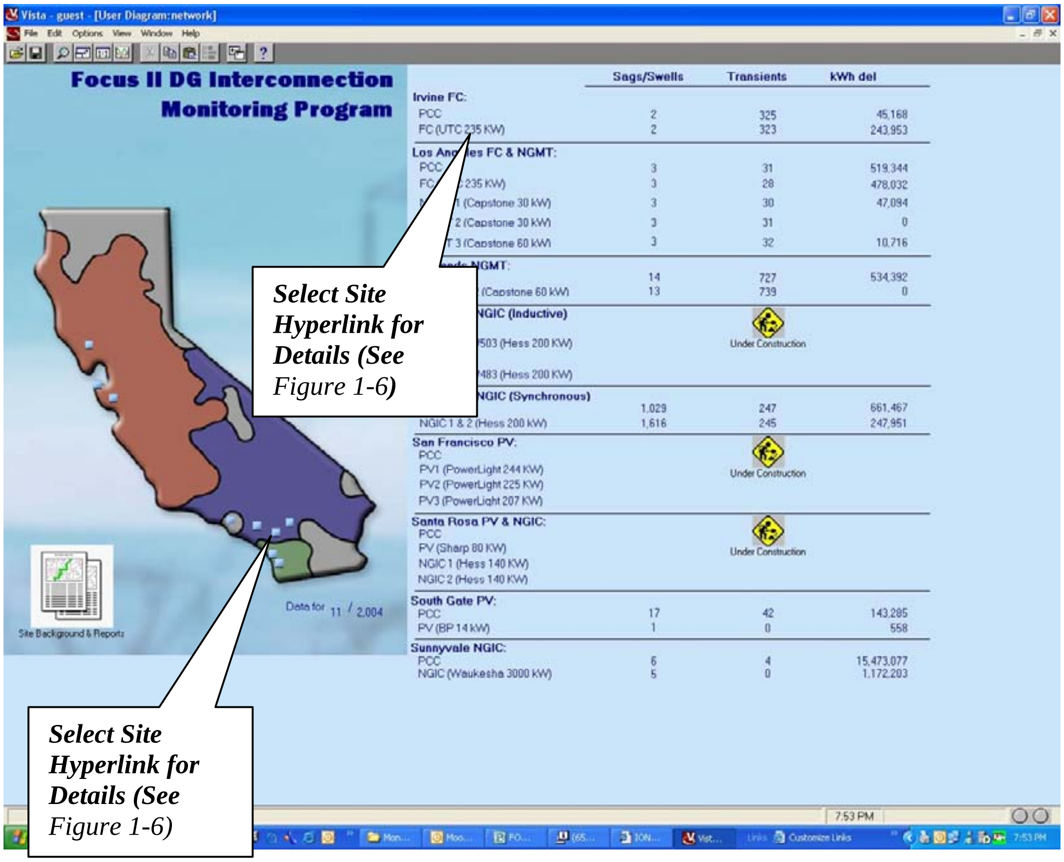
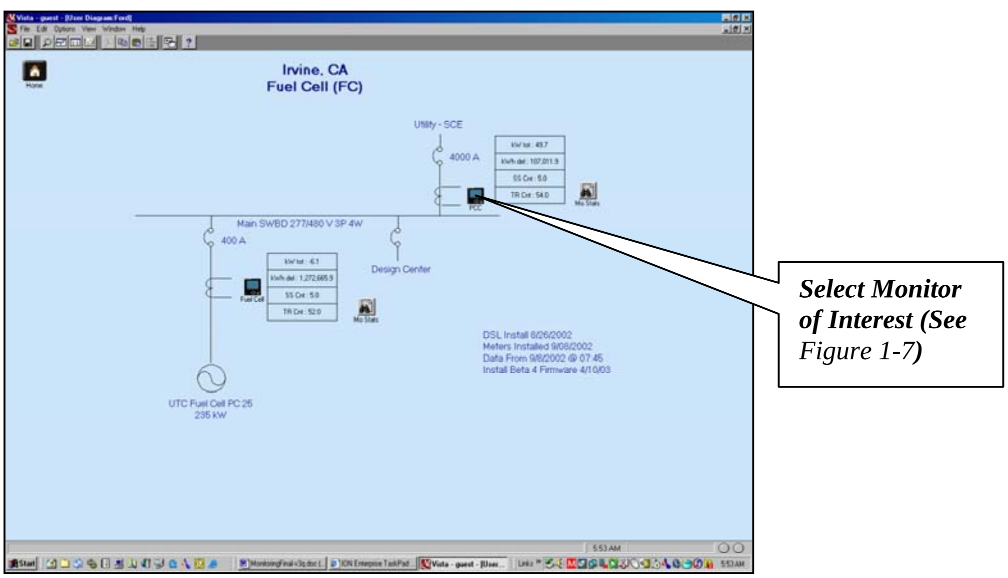


FIGURE 1-6: IRVINE SITE MAIN SCREEN (ONE-LINE DIAGRAM WITH MONITOR LOCATIONS)



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[11] All screen shots are from the website. For more information, latest information updates, and individual site data reports please visit FOCUS-II Monitoring Program website http://www.dgmonitors.com/.

FIGURE 1-7: IRVINE VOLTS/AMPS SCREEN

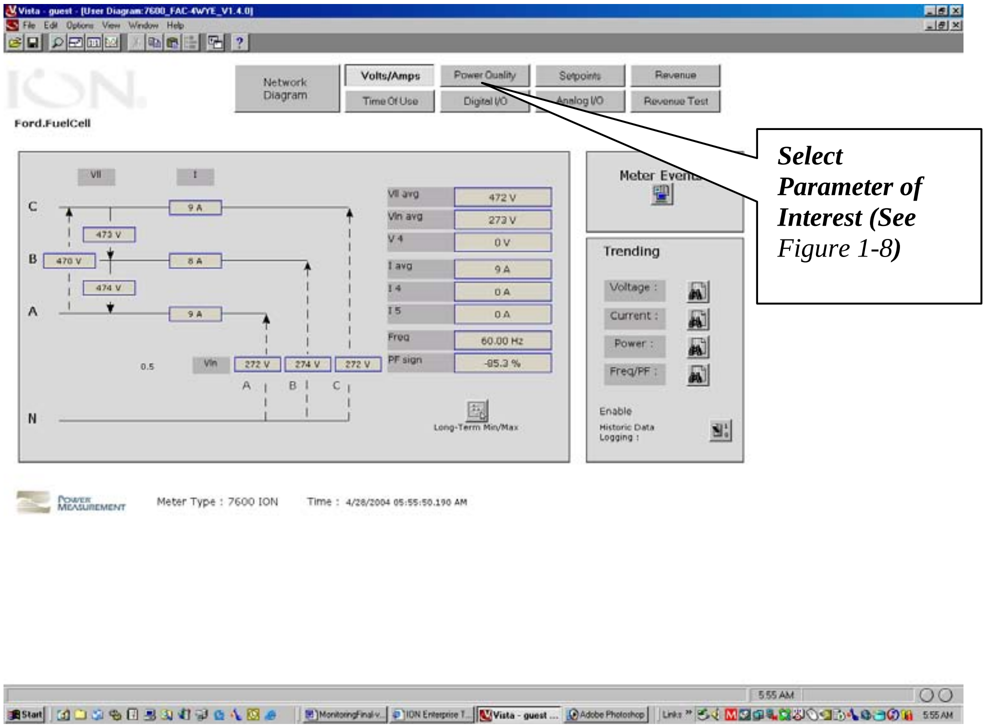
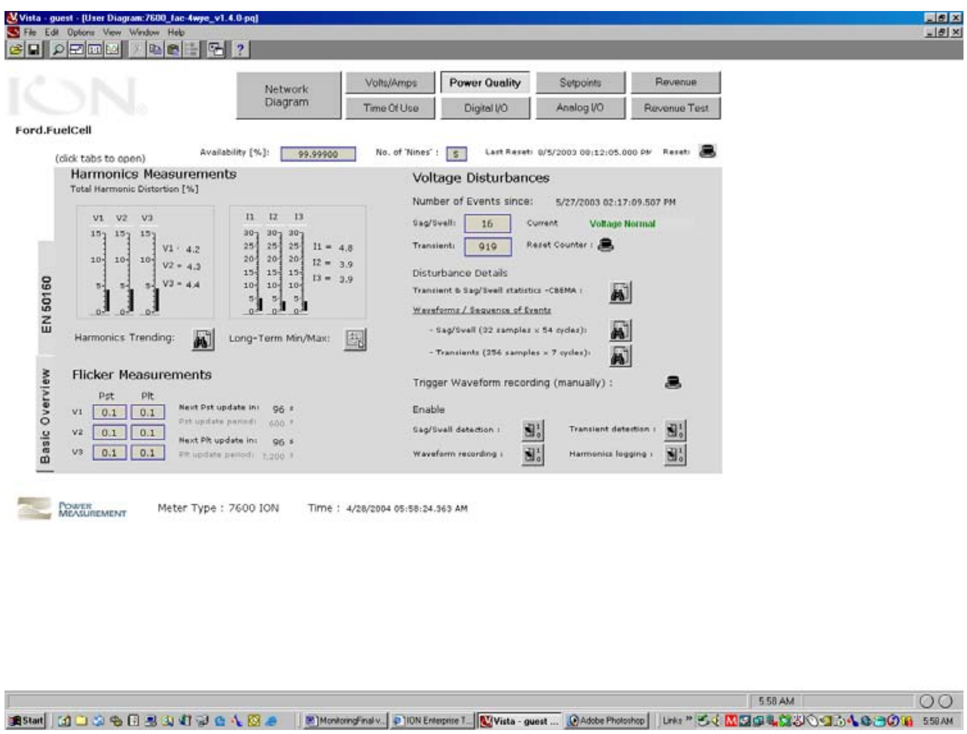


FIGURE 1-8: IRVINE POWER QUALITY SCREEN



1.1.7 Benefits and Limitations of the Program

This project provides a way to monitor the interface between the DG and distribution system and evaluate a range of new DG technologies. By studying the interface between the DG and the distribution system, it is hoped that the results will lead to cost-reductions during the DG installation application process by addressing and quantifying the impacts. The limitations, if any, are in the area of program and software limitations.

- Program Limitations – The program limitations are related to the Sample Size which only had six sites with seven different DG technologies being monitored.
- Software Limitations
    1. ION Report Generator – The ION Enterprise software came with a verity of generic reports but even these did not provide the required data analyses. Although several program-specific reports were developed, the segregation of the data based on DG operating mode had to be accomplished manually.
    2. Excel - One other limitation was related to the database size. The Report Generator performs analysis using Microsoft Excel and Excel has some inherent limitation based on data size. Because of the FOCUS database size was larger than Excel could handle, it had to be divided into smaller segments and then combined to provide the required analysis.

1.2 Schedule and Milestones

TABLE 1-4: PROJECT SCHEDULE AND MILESTONES

Milestones:	Date:
Project Planning	July to September 2001
Guidelines	September 2001 to February 2002
Test Plan	November 2001 to March 2002
Installation of Monitors	August 2001 to April 2002 December 2004
Configure, Startup and Checkout of Monitors, Firmware & ION Enterprise Software	March 2002 to August 2002 July 2004 to November 2004
Beginning Monitoring Period	August 2001 to December 2004
Analysis of Data Collected	January 2002 to October 2004
Final Report	December 2004

1.3 Data Analysis

During the planning stage, it was decided to use power quality as the tool to analyze the impact of DG on the distribution system and the impact of the distribution system on DG. This monitoring project developed a database of electric parameters for 15 power quality monitors at the DG and PCC. The data is analyzed using ION Enterprise™ web-ready software. The data collected is stored in an SQL database and the software has the capability to display real-time data and analyze logged information through a standard web browser. It can generate power quality, energy and load profile reports based on event or schedule. It also has the ability to analyze disturbances by plotting waveforms, ITI (CBEMA and SEMI voltage tolerance curves and histograms. All of theses features plus the program specific reports for Availability, Harmonic Distortion and SARFI were utilized in the development of this report.

We grouped the data by DG Technology and then compared periods of operation and with periods of non-operation. The analysis considers data in anticipation of achieving the following:

1. Understanding how certain Distribution/DG operations can impact system performance and determine its effect on power quality at the interconnection;
2. Assessing the DG Technology for typical electrical generation and the defining its power quality signature;
3. Identifying measures to improve power quality for the DG Interconnection;
4. Developing characterizations of DG Interconnection Power Quality;

The testing and analysis was designed to contribute to a streamlined application and installation process for new DG and to reduce the DG Interconnection costs.

1.4 Root Mean Square (RMS) Voltage Variations

1.4.1 RMS Voltage Variations

Voltage sags and interruptions are phenomena categorized by IEEE Std.1159-1995 as "RMS voltage variations". They are often the most important power quality concerns for customers. In general, customers understand that interruptions cannot be completely prevented on the power system. However, they are often less tolerant when their equipment fails or otherwise misoperates due to momentary disturbances that can be much more frequent than complete outages. These conditions are characterized by short-duration changes in the RMS voltage magnitude supplied to the customer. The impact on the customer depends on the voltage magnitude during the disturbance, the duration of the disturbance, and the sensitivity of the end-use equipment.

Voltage sags and interruptions are inevitable on the power system and are generally caused by faults on the utility system. Since it is impossible to completely eliminate the occurrence of faults, customers should decide how to protect voltage-sensitive loads from voltage variations. Storms are the most frequent causes of faults in most areas of the country. A storm passing through an area could result in dozens of major and minor power quality variations. On the utility system, protection schemes are designed to limit damage caused by unusual events such as faults caused by lightning strikes, and to localize the impact of such events to the smallest number of customers. This is often accomplished with overcurrent protection devices, such as reclosers, sectionalizers, and fuses. Voltage sags are frequently characterized by the magnitude of the voltage during the fault and the duration of the event.

1.4.2 SARFIx

If we consider just the incidents in which the minimum voltage fell below 0.90 per unit (called 0.9pu, meaning 90% of normal system voltage) and temporally aggregate them in a 60-second period, then we can compute an index known as $SARFI_{90}$. This index is a special case of SARFIx. SARFIx represents the average number of specified rms variation measurement events that occurred over the assessment period per customer served, where the specified disturbances are those with a magnitude less than X for sags or a magnitude greater than X for swells. SARFIx only includes IEEE Std. 1159-1995 short duration measurements (i.e., less than 60 seconds in duration).

$$SARFI_x = \frac{\sum N_i}{N_T} \qquad \textbf{(2-1)}$$

Where:

$x \equiv$ rms voltage threshold; with values - 140, 120, 110, 90, 80, 70, 50, and 10

$N_i \equiv$ number of customers experiencing short-duration voltage deviations with magnitudes above X% for X >100 or below X% for X <100 due to measurement event *I*

$N_T \equiv$ number of customers served from the section of the system to be assessed

Voltage regulation standard in North America vary from state to state and utility to utility. The national Standard in the U.S.A. is ANSI C84.1. Voltage regulation requirements are defined in two categories:

- Range A is for normal conditions and the required regulation is +/- 5% on a 120 volt base at the service entrance
- Range B is for short duration or unusual conditions. The allowable range for this condition is -8.3% to 5.8%.

Based on the Range B requirements, the monitors for this study were set for 88% (sag trigger) and 106% (swell trigger). For this reason, in addition to measuring voltage sags with $SARFI_{90}$, in this paper we measure voltage swells outside of the normal utility range with $SARFI_{100}$ to capture the swell events between 106% and 110%.

Note that the calculation of the SARFI index is not complete unless the number of customers impacted by the depressed voltage is known. That information is outside the scope of this project. We would have had to perform some sort of our power quality state estimation to determine the voltage sag experienced by customers throughout the systems we were monitoring. Without the added information provided by state estimation, the assessed system must be segmented so that every point in the system is contained within a section monitored by an actual power quality measuring instrument. Thus, the number of monitoring locations within the assessed system becomes the number of constant voltage segments upon which the indices are calculated. Because this process of monitor-limited segmentation (MLS) results in only a few segments per circuit, the calculated index values are less accurate than those calculated using state estimation concepts. Nonetheless, MLS still yields indices that are informative.

1.5 Voltage Harmonic Distortion

A fundamental objective of electric utility operations is to supply each customer with a constant sinusoidal voltage. The voltage signal at any point within the power system is ideally a constant sinusoidal signal that repeats at a rate of precisely 60 times per second. Although not perfect, the voltage signal produced by power system generators approximates a perfect sinusoid with a high degree of accuracy. Almost all load equipment connected to the electric power system has been designed to operate from a sinusoidal voltage source.

Harmonic distortion of the distribution system voltage originates with nonlinear devices on the power system. Nonlinear devices produce non-sinusoidal current waveforms when energized with a sinusoidal voltage. Examples of these devices include adjustable-speed drives (ASDs), switching power supplies (including computers and other office equipment), electronic ballasts in fluorescent lighting, battery chargers, saturated transformers, and arc furnaces. Nearly all of these are nonlinear and are shunt elements, and the majority shunt devices are loads.

Harmonic distortion problems range in severity from nuisance tripping of customer end-use equipment to complete failure of very expensive utility and customer equipment. For most customers, distribution system harmonic distortion levels are generally contained within acceptable limits, such that neither customer processes nor utility equipment are affected. Most power systems can absorb far more harmonic current than engineers might think. A large percentage of the problems occur when capacitors cause the system to be in resonance condition, thereby increasing the voltage distortion levels. Effects of harmonic distortion include heating in rotating machinery, failure of capacitor banks, telephone interference, and increased losses in system equipment.

1.5.1 Harmonic Distortion Assessment Indices

EPRI has developed several harmonic distortion indices to aid in the assessment of service quality for a specified circuit. The indices were defined such that they may be applied to systems of varying size. For example, the indices may be applied to measurements recorded across a utility's entire distribution system resulting in system averages, or the indices may be applied to a smaller segment of the distribution system, such as a single feeder or a single customer PCC. A system index value serves as a metric only and is not intended as an exact representation of the quality of service provided to each individual customer served from the assessed system. However, system index values can be used as a benchmark against which index values for various parts of the distribution system can be compared.

1.5.2 System Total Harmonic Distortion

System Total Harmonic Distortion (STHD95) represents the 95th percentile (CP95) value of a weighted distribution of the individual circuit segment THD distribution CP95 values. Consider a distribution of THD samples collected over a monitoring period for each circuit segment comprising the assessed system. A CP95 value can be calculated for each of the individual circuit segment THD distributions. Collectively, these CP95 THD values of these individual circuit segments comprise a system distribution of segment THD CP95 values. STHD95 is the CP95 of this system segment distribution.

1.5.3 System Average Total Harmonic Distortion

SATHD is based on the mean value of the distribution of voltage THD measurements recorded for each circuit segment rather than the CP95 value. SATHD represents the weighted average voltage THD experienced over the monitoring period normalized by the total connected kVA served from the assessed system.

1.6 Monthly & Quarterly Reports

Reports on the monitoring project and the power quality indices computed from the database of measurements collected during the project are available from the web. They are well organized and are saved in the Acrobat PDF format, which is readable with the freeware Adobe Acrobat Reader. The reports can be found at the URL: http://www.dgmonitors.com/

1.7 Power Quality & Parameters Being Monitored

A power quality disturbance is any variation in the voltage magnitude, frequency, or waveshape that might cause end-use equipment to misoperate. There are seven major types of disturbances:

- Voltage sags and swells
- Voltage interruptions
- Overvoltages and undervoltages
- Voltage flicker
- Harmonic distortion
- Voltage notching
- Transient disturbance

1.7.1 Voltage Sags and Swells

A voltage sag is a short-duration decrease of the rms voltage value, lasting from a ½ cycle to 120 seconds in duration.[12] These events are caused by faults on the power system or by the starting current of a relatively large motor or other large load. A voltage swell may accompany a voltage sag. A voltage swell occurs when a single-line-to-ground fault on the system results in a temporary voltage rise on the unfaulted phases. Removing a large load or adding a large capacitor bank can also cause voltage swells, but these events tend to cause longer duration changes in the voltage magnitude and will usually be classified as long-duration variations.

Sags and swells are short duration changes in the RMS level of the voltage. They typically last for less than a few seconds. Basically, sags and swells occur whenever there is a sudden change in the load current. Ohm's Law tells us that changes in the voltage occur when a changing current interacts with system impedance. If there is a sudden increase in current due to a load turning

[12] In this paper, we treat multiple events occurring within a 60 second event-window as single events. This practice is in conformance with IEEE Std. 1159-1995 for short duration measurements, i.e., less than 60 seconds in duration. This method of SARFI event segmentation is the same one followed by SCE and EPRI in their field power quality studies. By coincidence, only one series of sag events exceeded 60 seconds in data reported so far. It lasted 60.5 seconds—only 0.5 seconds over.

on, then sag will result. On single-phase circuits, a corresponding neutral-ground (N-G) swell also occurs. The effect on personal computers to a sag is often the loss of any data stored in volatile memory (such as RAM). This problem is not very prevalent in the newer laptop computers, which often run off of an internal battery, making them more immune to the effect of sags. Destruction of non-volatile memory (such as disk drive media) has also been experienced, particularly in older models, where the read/write head would be susceptible to contact with the media in the event of an uncontrolled shutdown.

If a load turns off, it produces a momentary increase, or swell, in the voltage. The greater the system impedance, the greater the magnitude of the disturbance. Swells, including N-G swells, can easily damage equipment. Power supplies controlling all manner of devices and IT systems are the most common victims of a swell.

Solutions to problems caused by voltage sags and swells are varied. Some examples include the installation of ferroresonant transformers, reprogramming a load's trip settings, adding ride-through to the load, and installing energy storage technologies, custom power devices, or UPS systems.

FIGURE 1-9: EXAMPLE SHORT DURATION RMS VOLTAGE WAVEFORMS

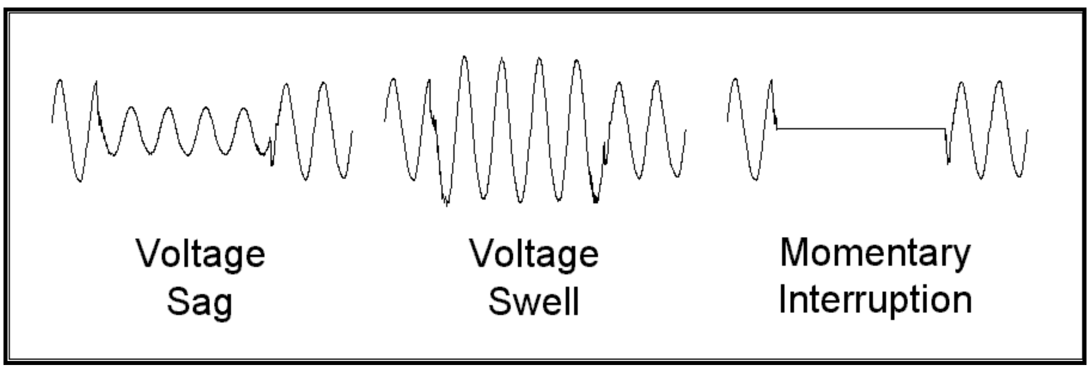
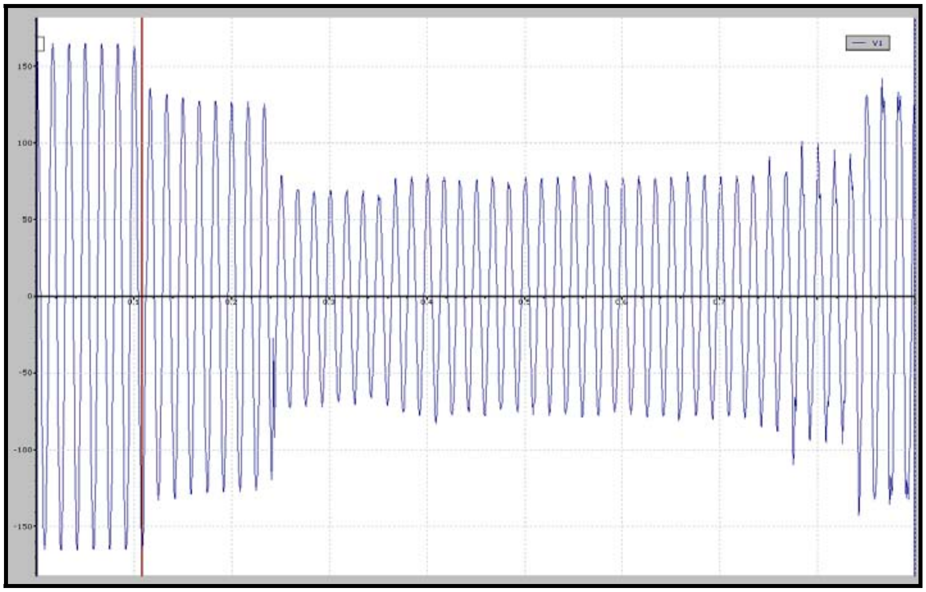


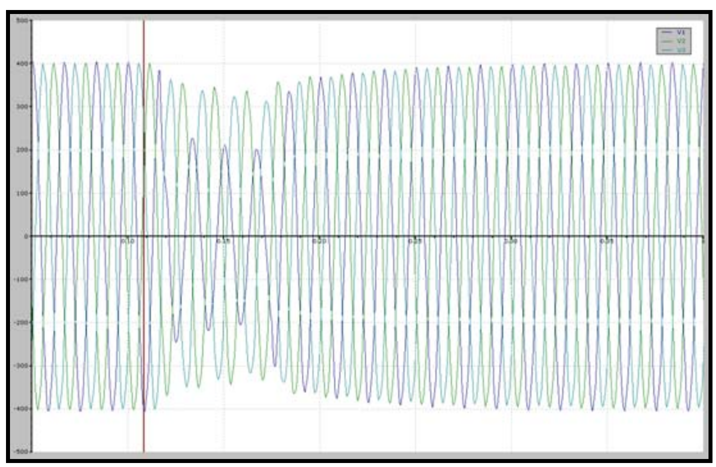
FIGURE 1-10: VOLTAGE SAG (38% FOR 0.783 SEC) [13] AT SOUTH GATE PCC DEC. 12, 2003 08:16:29



1.7.2 Voltage Interruption

A voltage interruption is the complete loss of electric voltage. Interruptions lasting less than 120 seconds are described as short-duration. If the duration exceeds 120 seconds, then the event is called long-duration. A disconnection of electricity causes an interruption, usually by the opening of a circuit breaker, line recloser, sectionalizer, or fuse. For example, if a tree comes into contact with an overhead electricity line, a circuit breaker may clear the fault, and the customers who receive their power from the faulted line will lose power and experience an interruption. The causes of interruptions are generally the same as the causes of voltage sags and swells.

FIGURE 1-11 VOLTAGE SAG (51% FOR 0.0750 SEC) AT SAN DIEGO NGIC OCTOBER 26, 2003 11:25:02



[13] The red vertical line is the event initiation or trigger of the event. Sag minimum voltage is 38% for 7 cycles (0.117 sec) and is the lowest rms value found during this event. The total event time is 0.783 sec from trigger to voltage restoration above the sag threshold of 90%.

Sags and voltage interruptions, however, do not directly cause damage; they initiate problems indirectly. For example, a sag may cause a laser CNC machine[14] to restart, thus damaging the product it was making. Manufacturing semiconductors is extremely sensitive to electricity supply variation. One brief voltage sag or interruption can cost millions of dollars in damaged or scrapped product, lost production and restarting expenses

1.7.2.1 System Faults

Customers located on the faulted feeder will experience one or more interruptions, depending on the type of fault and the reclosing practices of the utility. For a temporary fault, one or two reclosing operations may be required before normal power is restored. For a permanent fault, a number of reclosing operations (usually no more than four) will occur before the breaker "locks out" due to the permanent fault condition. In this case, the customers will experience a sustained interruption. Note that the interruptions associated with successive operations of the breaker may be of varying duration depending on relay characteristics. This gives the fault multiple opportunities to clear. The multiple operations also give sectionalizers the opportunity to operate. These devices typically open during the dead time after counting a certain number of consecutive incidents of fault current within a short time period. A sectionalizer typically will count to two, although it could be one if the sectionalizer is at the head of an underground cable where all faults are assumed to be permanent.

Reclosing practices vary from utility to utility and, perhaps, from circuit to circuit. Feeders that are mostly underground will typically not have any reclosing operations because most faults are permanent. Some utilities are experimenting with faster reclosing times (0.3 to 0.5 seconds) for the first reclosing operation in order to solve residential customer problems with momentary interruptions (residential electronic equipment such as clock radios, VCRs, microwaves, and televisions can often ride through 0.5 second interruptions but cannot ride through longer duration interruptions).

Customers located on parallel feeders (i.e., feeders that are supplied from the same bus as the faulted feeder) will experience a voltage sag for the duration that the fault remains on the line. On medium voltage systems, nearly all faults are cleared within one second and can be cleared in as short as three cycles, depending on the fault current magnitude and the relay settings. This means that customers on parallel feeders will experience at least one voltage sag lasting from three cycles to about one second and, possibly, additional voltage sags if reclosing operations are required.

If there are more than two feeders supplied from a common distribution bus, then voltage sags will occur more frequently than actual interruptions since a fault on any one feeder will cause voltage sags on all the other feeders.

Customers fed directly from the high voltage system (large, transmission-fed industrial customers, for example) usually have more than one line supplying the facility and actual interruptions should be very infrequent for these customers. However, these customers will experience voltage sags during fault conditions over a wide range of the transmission system.

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[14] Computer numerical control machines.

Voltage sags caused by high voltage system faults generally have more consistent characteristics. The faults that originate in the medium and low voltage systems tend to have more variation.

Since voltage sags can be much more frequent than actual interruptions, it is often important to consider the impacts and possible remedies for voltage sags separately from the required solutions for complete interruptions.

1.7.2.2 Overvoltages and Undervoltages

Long-duration voltage variations that are outside the normal limits (i.e., too high over 1.1 pu or too low 0.90 pu) are most often caused by unusual conditions on the power system. For example, out-of-service lines or transformers sometimes cause undervoltage conditions. These types of rms voltage variations are normally short-term, lasting less than one or two days. Voltage variations that last for a longer period of time are normally corrected by adjusting the voltage with a different tap setting of a step voltage regulating transformer.

The root cause of most voltage regulation problems is that there is too much impedance in the power system to properly supply the load. The load draws the current that gives a voltage drop across the system impedance. The resistive drop is in phase with the current and the reactive drop is 90 degrees out of phase. Therefore, the load voltage drops under heavy load. High voltages can come about when the source voltage is boosted to overcome the impedance drop and the load suddenly diminishes. These overvoltage conditions can cause problems with equipment that require constant steady-state voltage.

1.7.3 Voltage Flicker

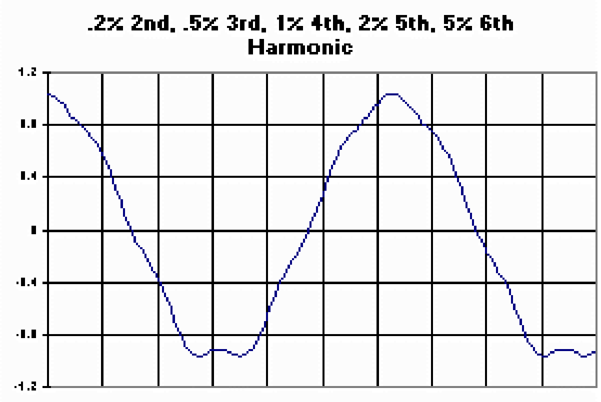
A waveform may exhibit voltage flicker if its waveform amplitude is modulated at frequencies less than 25 Hz, which the human eye can detect as a variation in the lamp intensity of a standard bulb. Voltage flicker is caused by an arcing condition on the power system. The arcing condition may be a normal part of a production process (e.g., a resistance welder or an electric arc furnace). Voltage step changes greater than 3% usually caused by the starting of large motors may also cause complaints of light flicker, but these events are not a frequency modulation of the voltage amplitude. Flicker problems can be corrected with the installation of filters, static var systems, or distribution static compensators. The monitor used in this project has the capability to report flicker statistics.

1.7.4 Harmonic Distortion

The phenomenon known as harmonic distortion is the presence of frequencies at integer multiples of the fundamental system frequency, which is 60 Hz for the North American system. Electronic loads and saturable devices generate harmonic distortion. Computers, lighting, and electronic office equipment generate harmonic distortion in commercial facilities. In industrial facilities, adjustable speed motor drives and other power electronic loads can generate significant amounts of harmonics.

It is generally safe to assume that the sine wave voltage generated in central power stations is very good. In most areas, the voltage found on transmission systems typically has much less than 1% percent distortion. However, the distortion may reach 5% to 8% as we move closer to the load. At some loads, the current waveforms will barely resemble a sine wave. Electronic power converters can chop the current into a variety of waveforms. Most distortion is periodic, and so is called harmonic distortion. That is, it is nearly the same cycle after cycle, changing very slowly, if at all. This has given rise to the widespread use of the term “harmonics” to describe perturbations in the waveform. This term must be carefully qualified to make sense.

FIGURE 1-12: EXAMPLE VOLTAGE WAVEFORM WITH HARMONIC DISTORATION



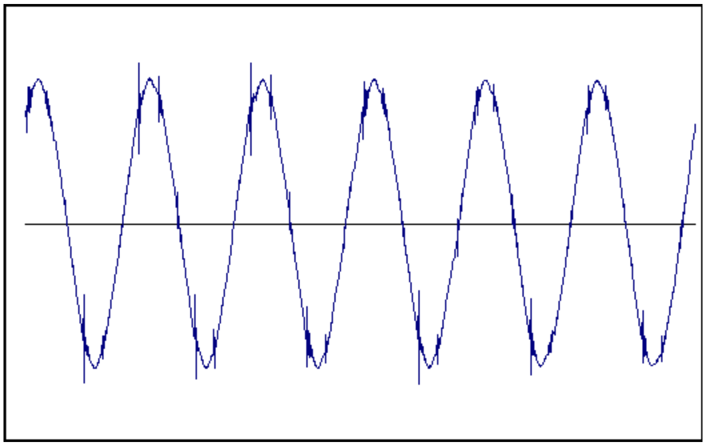
Solutions to problems caused by harmonic distortion include the installation of active or passive filters at the load or bus. Another solution is to take advantage of transformer connections that enable cancellation of zero sequence components

1.7.5 Voltage Notching

Voltage notching is caused by the commutation of power electronic rectifiers. It is an effect that can cause concern over power quality in any installation where converter equipment (a variable speed drive, for example) is connected. The effect is caused by the switching action of the drive’s input rectifier. When the drive dc link current is commutated from one rectifier thyristor to the next, there is an instant for which a line-to-line short circuit occurs at the input terminals to the rectifier. With this disturbance, any given phase voltage waveshape will typically contain four notches per cycle as caused by a six-pulse electronic rectifier.

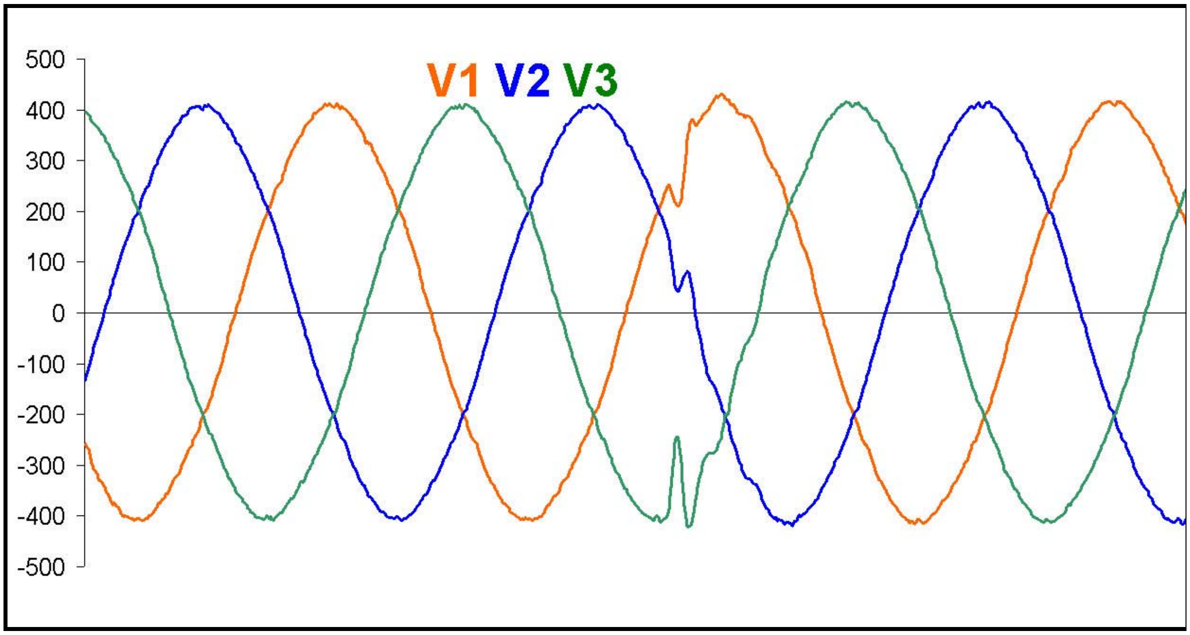
1.7.6 Transient Disturbances

FIGURE 1-13: EXAMPLE WAVEFORM WITH NOTCHING



Transient disturbances are caused by the injection of energy by switching or by lightning. The disturbance may either be unidirectional or oscillatory. Lightning, electrostatic discharge, load switching, or capacitor switching may cause a unidirectional transient. It is characterized by its peak value and rise time. An oscillatory transient is characterized by its frequency content, and may be caused by a switching operation such as the energization of a capacitor bank, distribution line, or cable, or the opening of an inductive current. Low and medium frequency oscillations, with principal frequencies less than 2 kHz, are normally caused by power system switching. The switching of a load close in proximity may cause high frequency oscillations with principal frequencies above 2 kHz. Common solutions to problems caused by transients include the application of surge arresters, passive and active filters, and isolation transformers.

FIGURE 1-14: EXAMPLE IMPULSIVE TRANSIENT WAVEFORM AT SAN DIEGO PCC NOV. 17, 2003



1.8 National Standards for Power Quality

Extensive work has been ongoing by IEEE in an effort to develop standards related to power quality. The following is the current list of active IEEE Standards working group (http://grouper.ieee.org/groups/) devoted to power quality:

- Power Quality - Data Interchange (P1159.3)
- Power Quality - Definitions (P1433)
- Power Quality - Event Characterization (P1159.2)
- Power Quality - Event Characterization: Data Acquisition (P1159.1)
- Power Quality - Harmonics Working Groups and Task Forces
- Power Quality - Monitoring Electric Power Quality (P1159)
- Power Quality - Standards Coordinating Committee SCC22
- Power Quality - Voltage Flicker (P1453)
- Power Quality - Voltage Sag Indices
- Power Systems - Harmonic Control (P519)

2 Monitor Availability

2.1 What is Monitor Availability?

Several early problems were encountered with communication and consistent receipt of data from the monitors. Even though the monitors were collecting good data, the transmission of the data through the internet proved to be a significant challenge. It was a good decision during the instrument selection process, that the 8 Mb memory option was incorporated into the monitors. This extra memory allowed short-term data storage at each site within the monitor. There was virtually no data permanently lost of data because of the PCC monitor going off-line (called "PCC lockup" or "Ethergate Lockup"). As a result of trouble-shooting and improvements in monitor firmware, the problems with communication and delivery of data have been significantly reduced.

Monitor availability is a measure of the time during the monitoring period that a power quality monitor was available for collecting data. Even though several communication problems occurred during this period, the overall availability average for the FOCUS-II Monitoring Program monitors was over 99%. The details by month is provided in Appendix A.

2.2 Reflective Energies Monitoring Project Activity Log

Appendix E provides notes on major monitoring project events. Primarily, Joseph Simpson of Reflective Energies and David Kidd of Power Measurement conducted the site visits to setup the installed monitors or to resolve issues and problems.

3 Power Quality, DG and the Distribution System

To understand the significance of the results of this monitoring study, it is useful to understand the context of interconnection requirements and customer requirements for power quality. Part 4 gives a brief context for understanding the importance of power quality to a customer that has one or more electricity generating facilities on-site interconnected in parallel with the distribution system. We will discuss the increased importance of power quality due to the vast proliferation of electronic devices used today in residential, commercial and industrial facilities; we will also discuss the regulatory interconnection requirements of facilities with on-site DG as they relate to power quality; and finally we will discuss customer power quality requirements.

3.1 The Importance of Power Quality in the Digital Economy

An economy based on electromechanical devices and processes can accept a wide band of power quality without being adversely affected. But an economy based on microprocessor control has much stricter power quality requirements. Power that is considered reliable for operation of simple mechanical devices may be highly unreliable for digital equipment. The situation is described in a recent Energy Commission publication:[15]

> Until recently, most electrical equipment could operate satisfactorily during expected deviations from the nominal voltage and frequency supplied by the utility. In the modern industrial facility, many electrical and electronic devices have been incorporated into the automated processes. No doubt that programmable logic controllers (PLCs), adjustable-speed drives (ASDs), energy efficient motors, CNC machines, and other power electronic devices increase productivity, increase the quality of products, and decrease the cost to customers of those products. However, they also increase the potential for problems with electrical compatibility because they are not as forgiving of their electrical environment as earlier technologies. As a result of this recent increase in equipment vulnerability, the owners of industrial processes have experienced unexplained process interruptions and unplanned equipment shutdowns.

Computers, digital controllers, and other electronic processes that are found in most industrial, commercial and even residential facilities can shut down when the voltage fluctuates from the nominal band. The proliferation of microelectronic devices, in everything from personal computers to manufacturing-process controllers, has radically changed end users' views about the importance of quality electric power. There have been recent studies indicating that 1.5 to 3.0 cents of every manufacturing sales dollar are now spent correcting power quality problems—a total of $25.6 billion per year.[16]

TABLE 3-1: MEASURING RELIABILITY

Reliability Percentage	Number of Nines	Yearly Downtime in Seconds
99%	2	315,360.00
99.9%	3	31,536.00
99.99%	4	3,153.60
99.999%	5	315.36
99.9999%	6	31.54
99.99999%	7	3.15

[15] California Energy Commission, "Power Quality Solutions for Industrial Customers: A Guidebook", August 2000.
[16] Revis, James. "Scoping Study on Trends in the Economic Value of Electricity Reliability to the U.S. Economy". EPRI. June 2001. <http://ceids.epri.com/ceids/Docs/LBNL_executive.pdf>.

The development of electrical devices that are increasingly sensitive to power fluctuations makes the stability and reliability of the power system perhaps the most important technical issue to be addressed in the near future by the utilities. [17]

The need for reliable power (that is, the lack of interruptions) is often measured in seconds of downtime per year. Seconds of downtime divided by total seconds in a year gives a reliability percentage in "9's". Yet, the New York blackout notwithstanding, this measure is an insufficient gauge of reliable power for a microprocessor-based society. Today, it is not only when the utility power drops to zero that a customer may suffer from unreliable power. In fact, today customers may suffer loss from any of the seven power quality disturbances described in Section 1.7. IEEE Standard 1159-1995, *Recommended Practice on Monitoring Electric Power Quality*, provides a common terminology that can be used to discuss and assess all forms of power quality disturbance. RMS voltage variations, the most common forms of disturbance that customers face —voltage sags and swells, interruptions, overvoltages and undervoltages—are shown in Table 3-2.

TABLE 3-2: RMS CATEGORIES FROM IEEE 1159-1995

Category	*Duration*	*Voltage Magnitude*
Short Duration Variations		
Instantaneous		
Sag	0.5 to 30 cycles	0.1 to 0.9 pu
Swell	0.5 to 30 cycles	1.1 to 1.8 pu
Momentary		
Interruption	0.5 cycles to 3 s	< 0.1 pu
Sag	30 cycles to 3 s	0.1 to 0.9 pu
Swell	30 cycles to 3 s	1.1 to 1.8 pu
Temporary		
Interruption	3 s to 1 min	< 0.1 pu
Sag	3 s to 1 min	0.1 to 0.9 pu
Swell	3 s to 1 min	1.1 to 1.8 pu
Long Duration Variations		
Sustained Interruption	> 1 min	0.0 pu
Undervoltage	> 1 min	0.8 to 0.9 pu
Overvoltage	> 1 min	1.1 to 1.2 pu

With the addition of DG to an end user's power mix, providing the level of reliability and power quality required by each customer becomes the shared responsibility of the DG owner/operator and the local utility owning and operating the distribution grid. Little is known about how DG affects the grid, or how the grid affects DG—or how either one affects customer power quality. Both EPRI and SCE have done studies on distribution system power quality.[18] One of the most interesting results this FOCUS-II monitoring study promises to provide is a side-by-side comparison of DG power quality characteristics (by technology) with those of the distribution system. Besides assessing the DG /grid interaction, the data will provide an unprecedented look at the effect of DG on customer power quality.

Before DG can even begin operation, however, it must interconnect to the distribution system; and before it can interconnect, it must satisfy utility requirements that protect the distribution system. Some of these requirements regulate power quality disturbances coming from the DG and some regulate what the DG must do when disturbances come from the distribution system itself.

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[17] FitzPatrick, Gerald J. "Measurement Support for the U.S. Electric-Power Industry in the Era of Deregulation". May 1997.
[18] See Footnote **Error! Bookmark not defined.** and Footnote **Error! Bookmark not defined.**.

3.2 Power Quality Requirements for Interconnection

In order to interconnect DG to the distribution system, a customer (and third-party provider, if applicable) must sign an interconnection agreement with the utility. The purpose of this agreement, and the requirements it represents, is to ensure the safety and reliability of the distribution system and to set out the rights and obligations of the parties. Within the territories of the investor-owned utilities in California, the interconnection process is regulated by the CPUC-approved interconnection tariff Rule 21 (discussed above in the Executive Summary). As Rule 21 Section D.1.g states, “These requirements are designed to protect [the Utility’s] Distribution System and not the Generating Facility.”

There are a number of power quality requirements of the DG within Rule 21, particularly Section D, including over/under voltage, over/under frequency, flicker, and harmonic distortion. The introduction to Section D., entitled “Prevention of Interference” states:[19]

> The Electricity Producer shall not operate equipment that superimposes upon the Distribution System a voltage or current that interferes with [Utility] operations, service to [Utility] Customers, or [Utility] communication facilities. If such interference occurs, the Electricity Producer must diligently pursue and take corrective action at its own expense after being given notice and reasonable time to do so by [Utility]. If the Electricity Producer does not take timely corrective action, or continues to operate the equipment causing interference without restriction or limit, [Utility] may, without liability, disconnect the Electricity Producer's equipment from the Distribution System...

3.2.1 Over/Under Voltage

Under/overvoltage is defined is a longer-term voltage over- or under-supply relative to the line voltage lasting up to several days (as described in this report Section 1.7.2.2). Section D.1.b states that the DG must include a trip function for over/under voltage and a means for disconnecting the DG from the distribution system in the event of a trip.

The DG must match the line voltage, within a range of 88% to 110% of nominal line voltage. If the DG or the distribution line goes outside of this range, the DG must trip and disconnect, as described above. In some situations, generators larger than 11kVA may be required to stay online for voltage support. Otherwise, the rules for trip time[20] for all generators (assuming a 120 volt line) are as shown in Table 3-3.

TABLE 3-3: RULE 21 TRIP TIMES FOR OVER/UNDER VOLTAGE

Voltage at Point of Common Coupling	Maximum Trip Time (Assuming 60 Cycles per Second)
Less than 60 volts	10 cycles
Greater than 60 volts but less than 106 volts	120 cycles
Greater than 106 volts but less than 132 volts	Normal Operation
Greater than 132 volts but less than 165 volts	120 cycles (30 cycles for facilities greater than 11kVA)
Greater than 165 volts	6 cycles

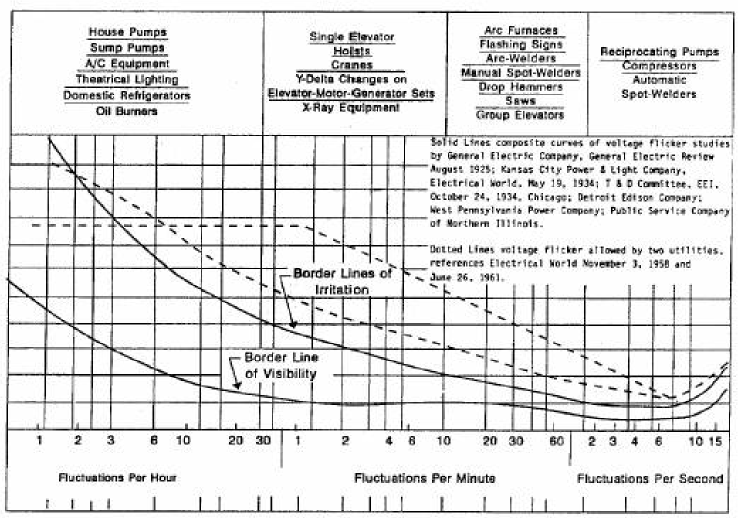
[19] Links to the 3 IOUs’ Rule 21 documents are on the Energy Commission website: http://www.energy.ca.gov/distgen/interconnection/california_requirements.html

3.2.2 Over/Under Frequency

Under/over frequency is not usually considered a power quality disturbance; because frequency is a quality of power, however, we will consider it among the other forms of power quality regulated by Rule 21. The distribution system typically operates at about 60 hertz. Section D.1.b states that the DG must include a trip function for over/under frequency and a means for disconnecting the DG from the distribution system in the event of a trip. Rule 21 Section D.2.c states that the DG must operate in synchronism with the distribution system within the range of 59.3 to 60.5 hertz. Should the utility remain outside the frequency limits, the DG must cease to energize the system and a maximum of 10 cycles. The time delay allows the DG to ride through short-term disturbances to avoid nuisance tripping. As with over/under voltage, the utility may require generators larger than 11 kVA to assist during capacity shortages.

3.2.3 Flicker

FIGURE 3-1: MAXIMUM BORDERLINE OF IRRITATION CURVE



The phenomenon of flicker is just what the name implies: a variation in intensity of light output from a standard incandescent bulb. Flicker may be caused by modulation of waveform amplitude at frequencies less than 25 hertz, by an arcing condition causing a loss of voltage, or by voltage step changes greater than 3%. Rule 21 requirements aim to reduce flicker at customer facilities on the same feeder as a customer with DG. In most cases, flicker is not an issue for any DG except for a rotating prime mover with an induction generator. Like a large motor, an induction machine starts up by motoring up to the speed of the distribution system while it draws down facility voltage. Section D.2.b sets flicker limits not to exceed the "Maximum Borderline of Irritation Curve"[21]

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[20] Rule 21 contains the following note: " 'Trip time' refers to the time between the abnormal condition being applied and the Distributed Generator unit ceasing to energize the Distribution System. Certain circuits will actually remain connected to the Distribution System to allow sensing of electrical conditions for use by the "reconnect" feature. The purpose of the allowed time delay is to ride through short-term disturbances to avoid excessive nuisance tripping. For systems of 11 kVA peak capacity or less, the above set points are to be non-user adjustable. For Distributed Generator units larger than 11 kVA, different voltage set points and trip times from those in the above Table may be negotiated with SDG&E."

[21] "Recommended Practices and Requirements for Harmonic Control in Electric Power Systems", IEEE STD 519-1992, Institute of Electrical and Electronic Engineers, Piscataway, NJ. April 1992.

In Rule 21 Section I, Screen 5 asks "Is the Starting Voltage Drop screen met?" The utility has two methods for determining whether starting voltage drop could be a problem:

> Option 1: The Generating Facility starting Inrush Current must be equal to or less than the continuous ampere rating of the Customer's Service Equipment.
>
> Option 2: Determine the impedances of service distribution transformer (if present) and secondary conductors, from primary to Customer's Service Equipment. Perform voltage drop calculation, or alternately use SDG&E's tables or nomographs. Voltage drop must be less than 2.5% for primary interconnection and 5% for secondary interconnection.

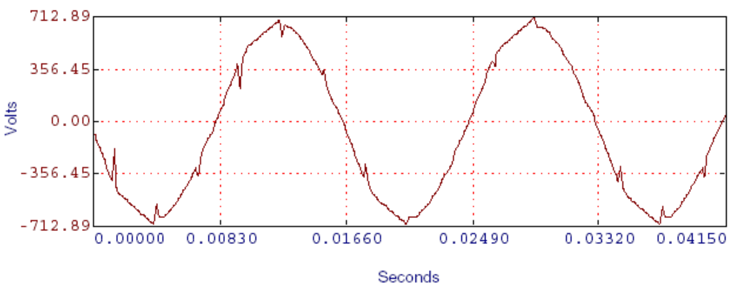
The utility may use either option at its discretion.

3.2.4 Harmonic Distortion

Rule 21 Section D.2.d states:

> Harmonic distortion shall be in compliance with IEEE 519. Exception: The harmonic distortion of a Distributed Generator at a Customer's site shall be evaluated using the same criteria as the loads at that site.

FIGURE 3-2: WAVEFORM WITH 5% TOTAL HARMONIC DISTORTION .



For electrical systems operating at 69 kV and below, IEEE 519-1992 limits the voltage Total Harmonic Distortion to 5% and requires that no individual harmonic should be above 3% of the fundamental.

3.2.5 Anti-Islanding Provisions

Utility provisions for anti-islanding attempt to prevent a generator from energizing a utility feeder after an interruption have occurred on the distribution system. The danger is that utility line personnel attempting to restore power after an outage would not know that the DG feeder was "hot" and consequently suffer electrocution.

Section D.1 of Rule 21, the general requirements section, has three provisions that work to prevent an "unintended island":[22]

> D.1.a: Protective Functions shall be equipped with automatic means to prevent the Generating Facility from re-energizing a de-energized Distribution System circuit.
>
> D.1.c: The Generating Facility and associated Protective Functions shall not contribute to the formation of an Unintended Island.

[22] An island is defined in Rule 21 (Section H) as: "A condition on the Distribution System in which one or more Generating Facilities deliver power to Customers using a portion of the Distribution System that is electrically isolated from the remainder of the Distribution System." An unintended island is defined as "...creation of an island, usually following a loss of a portion of the Distribution System, without the approval of SDG&E."

.

D.1.e: Protective Functions shall be equipped with automatic means to prevent reconnection of the Generating Facility with the Distribution System unless the Distribution System service voltage and frequency is of specified settings and is stable for 60 seconds.

Screen #2 in Section I of Rule 21 asks, “Will power be exported across the PCC?” If the DG fails Screen #2 (by answering ‘Yes’), the applicant has three options according to Section D.3.d.1:

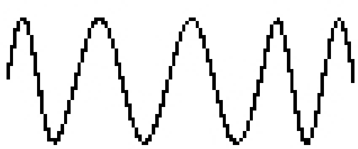
- Incorporate certified non-islanding control functions into its set of protective functions; or
- Verify that local loads sufficiently exceed the load carrying capability of the generator so that export would not occur; or
- Implement a transfer trip or equivalent function.

3.3 Customer Power Quality Requirements

These disturbances range in customer experience from scarcely perceptible minutia to multimillion-dollar problems. The potential damage a disturbance can cause depends on its type and severity, and on the nature of the customer facility: the end use devices used and their exposure to the particular disturbance.

As mentioned in Section 1.7, there are seven major types of disturbances that can affect customer operations adversely. Although a complete discussion of the impacts these power quality disturbances can have on electronic equipment is beyond the scope of this paper, it will be useful nonetheless in interpreting the data results of this monitoring study to have a better idea of what kinds of problems these disturbances may cause to end-use equipment.

TABLE 3-4: FREQUENCY VARIATION

Power Quality Disturbance	Classification	Probable Cause	Equipment Impacts
Frequency Variation [23] 	The deviation of the power system fundamental frequency from its specified nominal value (50 or 60 Hz)	1. Poor speed regulation of local generation 2. Faults on the bulk power system 3. Large block of load being disconnected 4. Disconnecting a large source of generation	Equipment failure

[23] Data analysis and research of the waveforms was unable to find any Frequency Variation events.

.

TABLE 3-5: INTERRUPTIONS

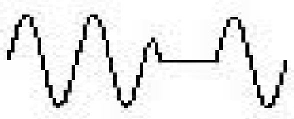
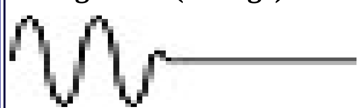
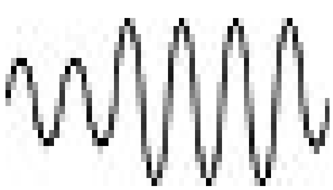
Power Quality Disturbance	Classification	Probable Cause	Equipment Impacts
Interruptions[24] **Momentary**  **Temporary**  **Long Term (Outage)** 	Duration of ½ to 3 sec. Duration of 3 to 60 sec. Duration of > 1 minute	1. Temporary Faults 2. Lighting stroke 3. Tree limb failing across two conductors then dropping clear 4. Faults that do not clear	Operation interruption, production losses, and revenue losses

TABLE 3-6: LONG DURATION VOLTAGE VARIATION

Power Quality Disturbance	Classification	Probable Cause	Equipment Impacts
Overvoltage [25] 	Increase in the rms ac voltage greater than 110 percent at the power frequency for a duration longer than 1 minute	1. Load switching off 2. Capacitor switching on 3. System voltage regulation	Problems with equipment that require constant steady-state voltage
Undervoltage [26] 	Decrease in the rms ac voltage to less than 90 percent at the power frequency for a duration longer than 1 minute	1. Load switching on 2. Capacitor switching off 3. System voltage regulation	Problems with equipment that require constant steady-state voltage

[24] Data analysis and research of the waveforms revealed no incidence of momentary interruption (voltage drop to zero for up to 3 seconds), no incidence of temporary interruption (voltage drop to zero for between 3 to 60 seconds), and no incidence of long term interruption (i.e., outages—voltage drop to zero for more than 1 minute).

[25] Data analysis and research of the waveforms did not find any Long Term Overvoltage events.

[26] Data analysis and research of the waveforms did not find any Long Term Undervoltage events.

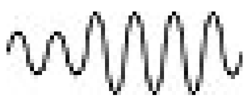
Power Quality Disturbance	Classification	Probable Cause	Equipment Impacts
Overvoltage [27] 	Increase in the rms ac voltage greater than 110 percent at the power frequency for a duration longer than 1 minute	1. Load switching off 2. Capacitor switching on 3. System voltage regulation	Problems with equipment that require constant steady-state voltage
Undervoltage [28] 	Decrease in the rms ac voltage to less than 90 percent at the power frequency for a duration longer than 1 minute	1. Load switching on 2. Capacitor switching off 3. System voltage regulation	Problems with equipment that require constant steady-state voltage

TABLE 3-7: SHORT DURATION VOLTAGE VARIATION

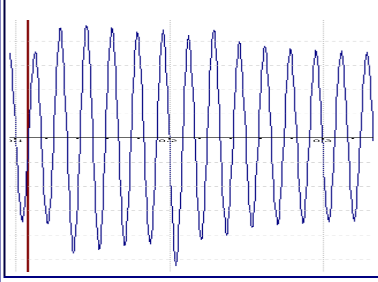
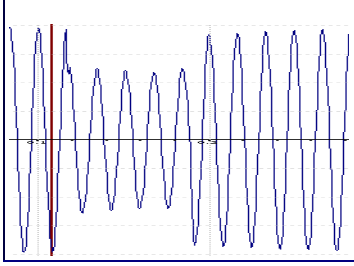
Power Quality Disturbance	Classification	Probable Cause	Equipment Impacts
Voltage Swell [29] **(Surges)** 	Increase to between 1.1 and 1.8 pu in the rms voltage or current at the power frequency for durations from 0.5 cycle to 1 min.	Single-line-to ground faults	1. Equipment overvoltage 2. Failure of MOVs forced into conduction
Voltage Sag [30] **(Dips)** (Redlands PCC 2/19/04 08:45:57 59% for 0.084 sec) 	Decrease between 0.1 and 0.9 pu in rms voltage or current at the power frequency for duration of 0.5 cycles to 1 min.	Local and remote faults	Drop out of sensitive customer equipment

FIGURE 3-3: REDLANDS 11/25/02 EVENTS

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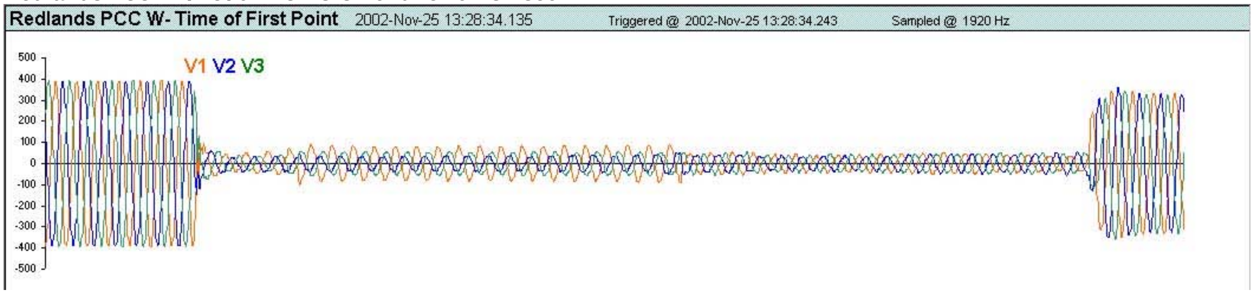
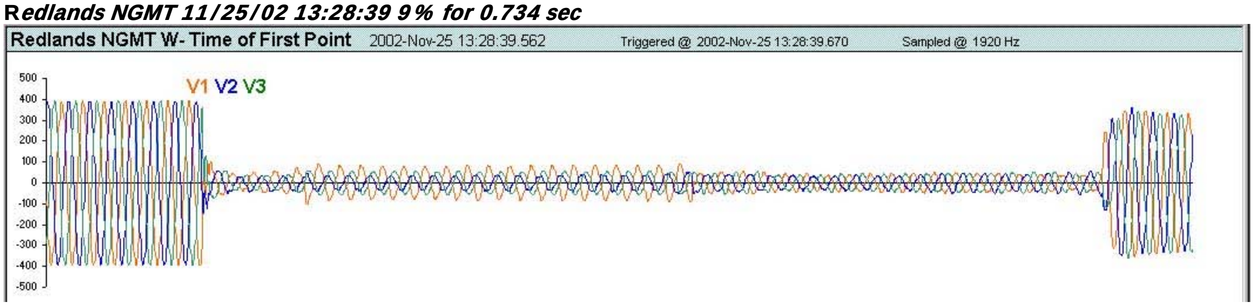
[27] Data analysis and research of the waveforms did not find any Long Term Overvoltage events.

[28] Data analysis and research of the waveforms did not find any Long Term Undervoltage events.

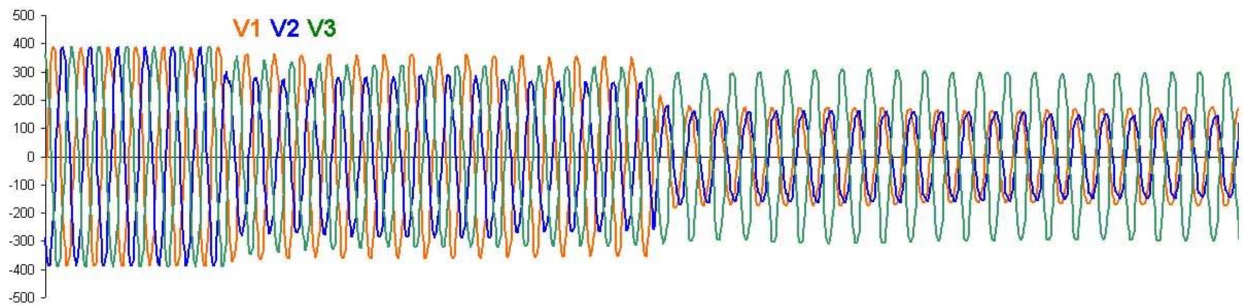
Redlands PCC 11/25/02 13:28:34 9% for 0.734 sec



Redlands NGMT 11/25/02 13:28:39 9% for 0.734 sec



Redlands PCC 11/25/02 13:21:56 16% for 0.975 sec



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29 Data analysis and research of the waveforms did not find any Voltage Swell (Surges) greater than 1.1 pu. The San Diego site experienced many swell events but they were in the range of 0.98 to 1.08 pu. None of these events exceed the 1.1 pu criteria and therefore were not great enough to be classified in the $SARFI_{110}$ category.

30 Data analysis and research of the waveforms found some Voltage Sag (Dips) Momentary Interruptions. The Redlands event (11/25/02 13:28:33 PCC & 13:28:40 NGMT ***Figures 1-1 & 1-2***) had a voltage decrease to 9% pu for 0.734 sec. Some of the major events where the voltage drop to 50% or below are captured in ***Figures 4-10 to 4-16.*** None of these events resulted in any equipment failures.

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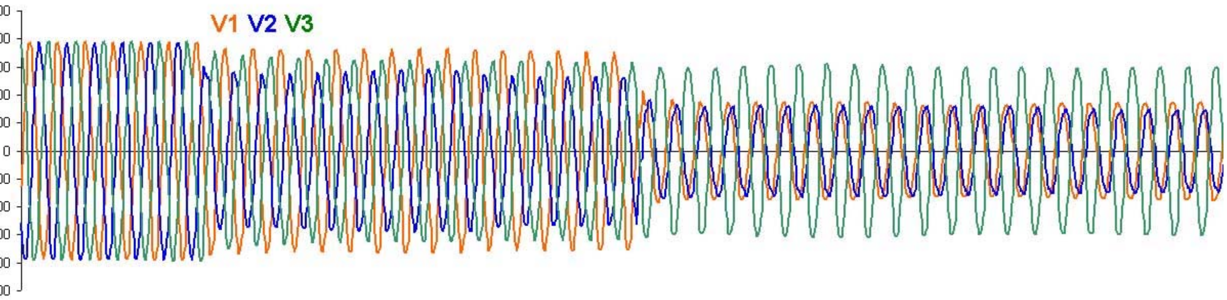
Redl Redlands NGMT 11/25/02 13:21:56 16% for 0.976 sec



Redlands NGMT 11/25/02 13:22:03 16% for 0.976 sec

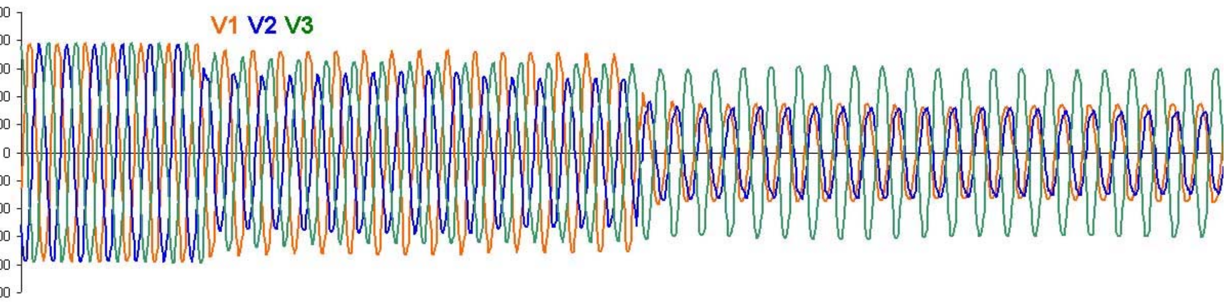
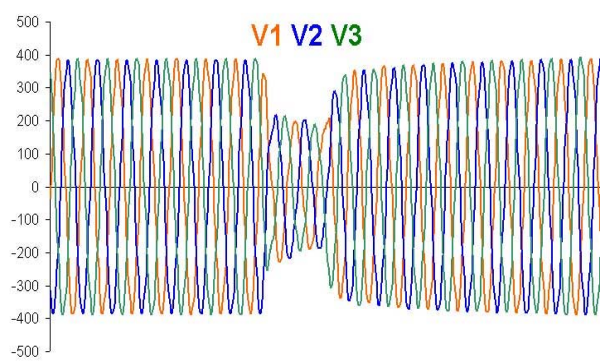


FIGURE 3-4: REDLANDS 11/15/02 EVENTS

Redlands PCC 11/15/02 01:04:12 50% for 0.058 sec



Redlands NGMT 11/15/02 01:04:12 48% for 0.050 sec

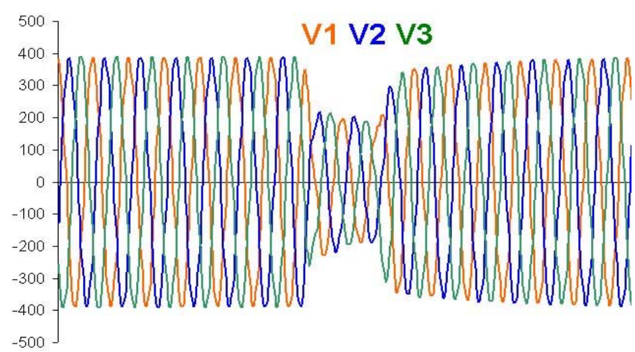
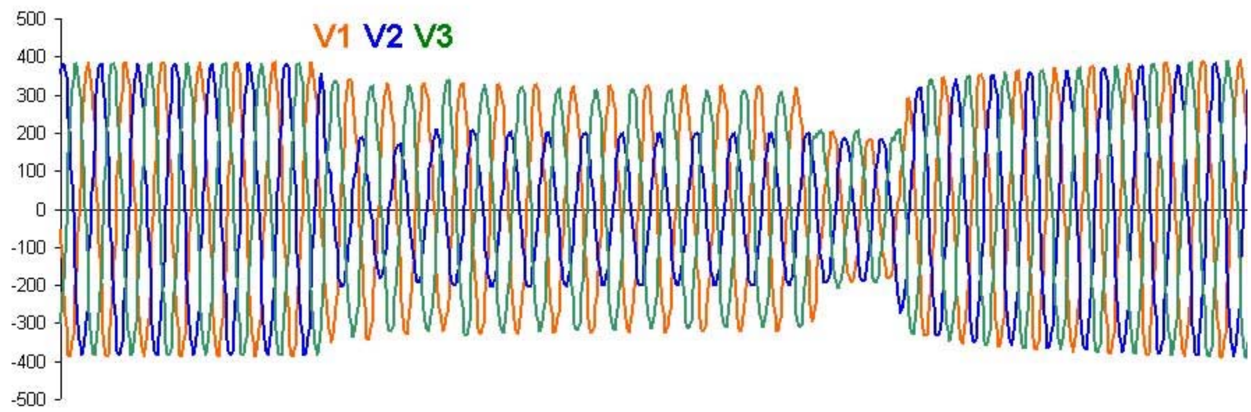


FIGURE 3-5: REDLANDS 04/07/03 EVENTS

Redlands PCC 04/07/03 00:25:50 44% for 0.283 sec



Redlands NGMT 04/07/03 00:25:50 45% for 0.292 sec

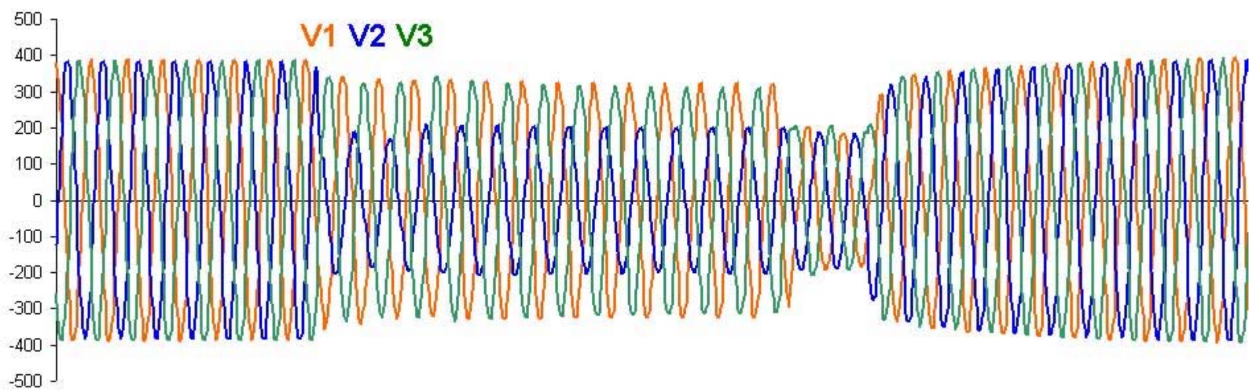
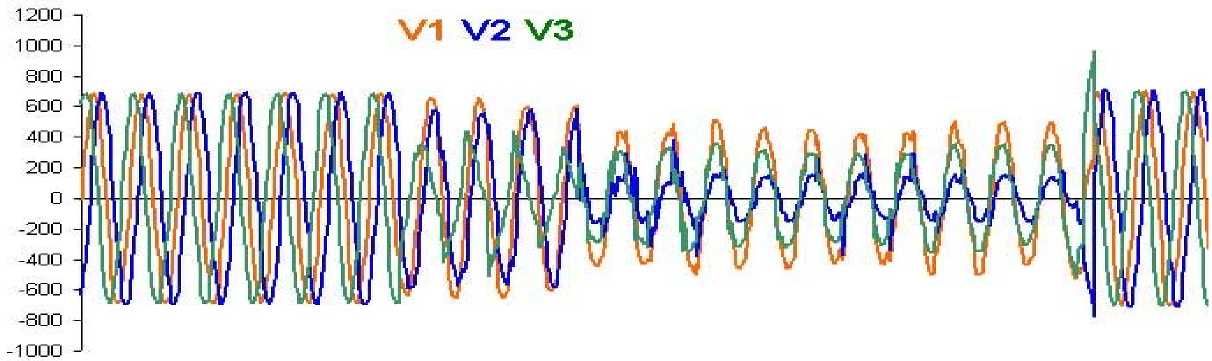
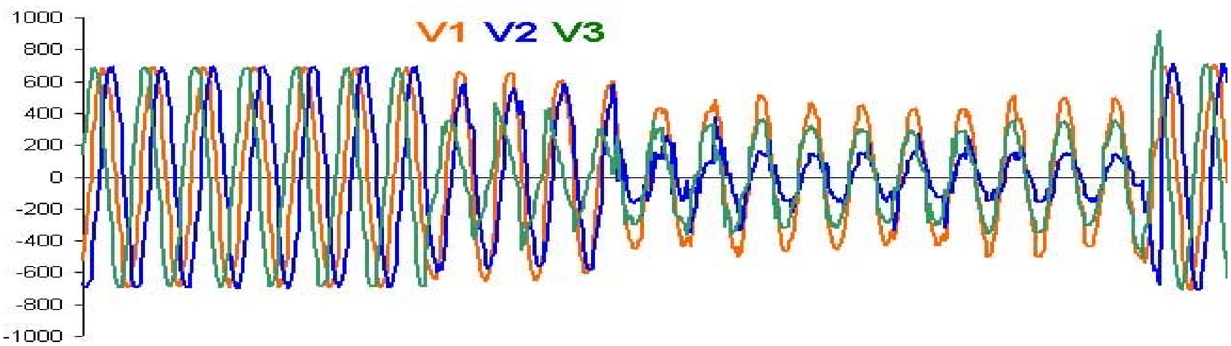


FIGURE 3-6: LOS ANGELES 06/30/03 EVENTS

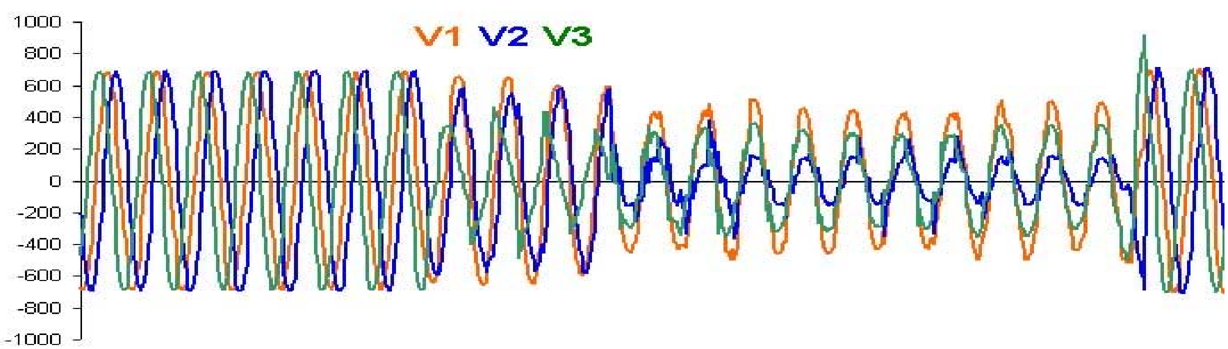
Los Angeles PCC 06/30/03 01:01:29 21% for 0.241 sec



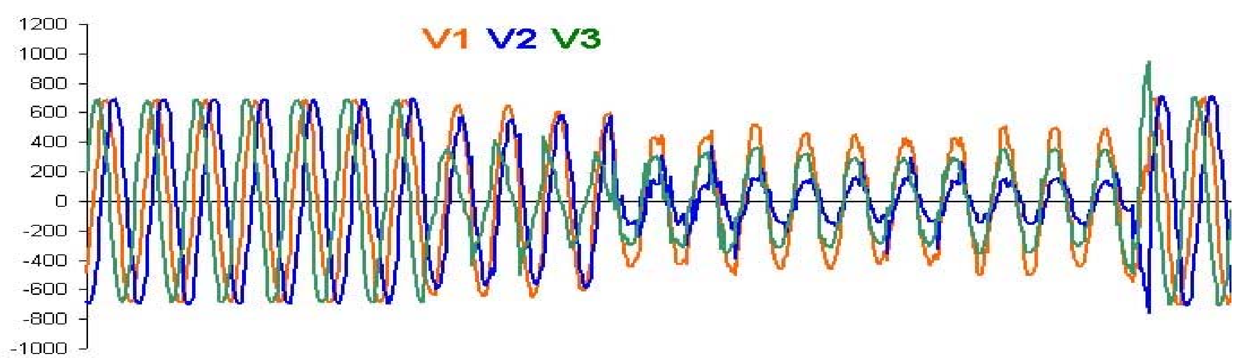
Los Angeles FC 06/30/03 01:01:29 21% for 0.241 sec



Los Angeles NGMT1 06/30/03 01:01:29 22% for 0.250 sec



Los Angeles NGMT2 06/30/03 01:01:29 21% for 0.241 sec



Los Angeles NGMT3 06/30/03 01:01:30 23% for 0.241 sec

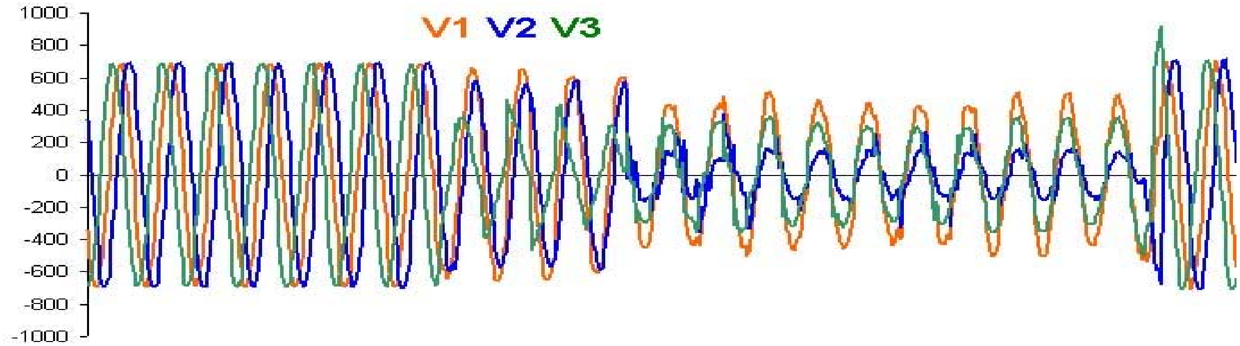
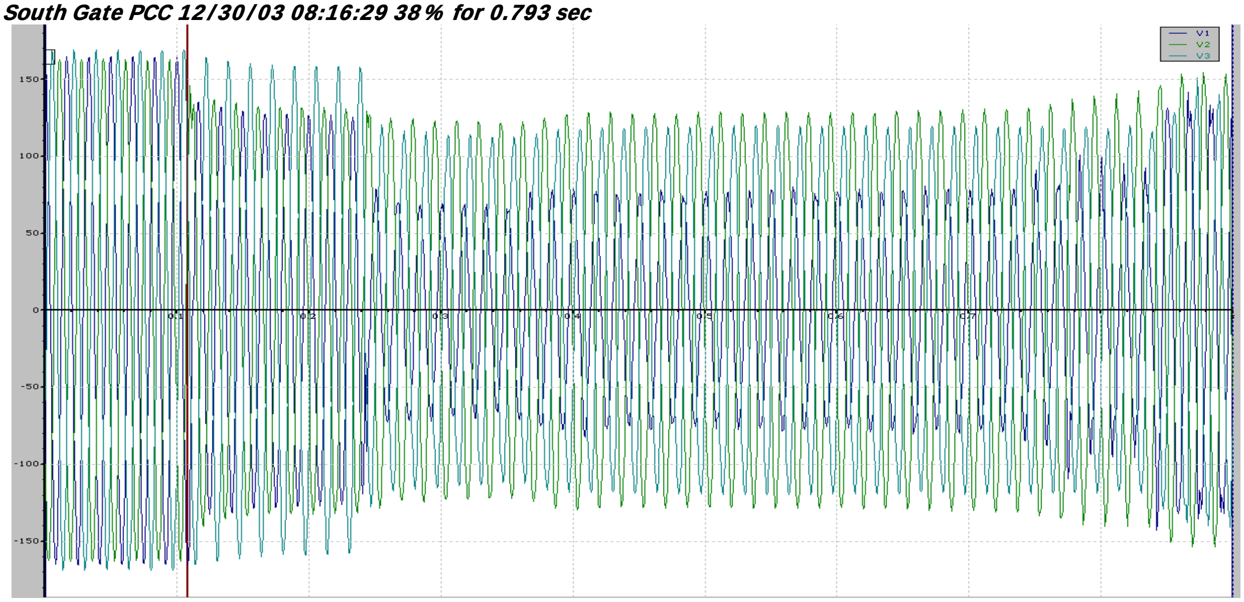


FIGURE 3-7: SOUTH GATE 12/30/03 EVENTS

South Gate PCC 12/30/03 08:16:29 38% for 0.793 sec



South Gate PV 12/30/03 08:16:28 38% for 0.801 sec

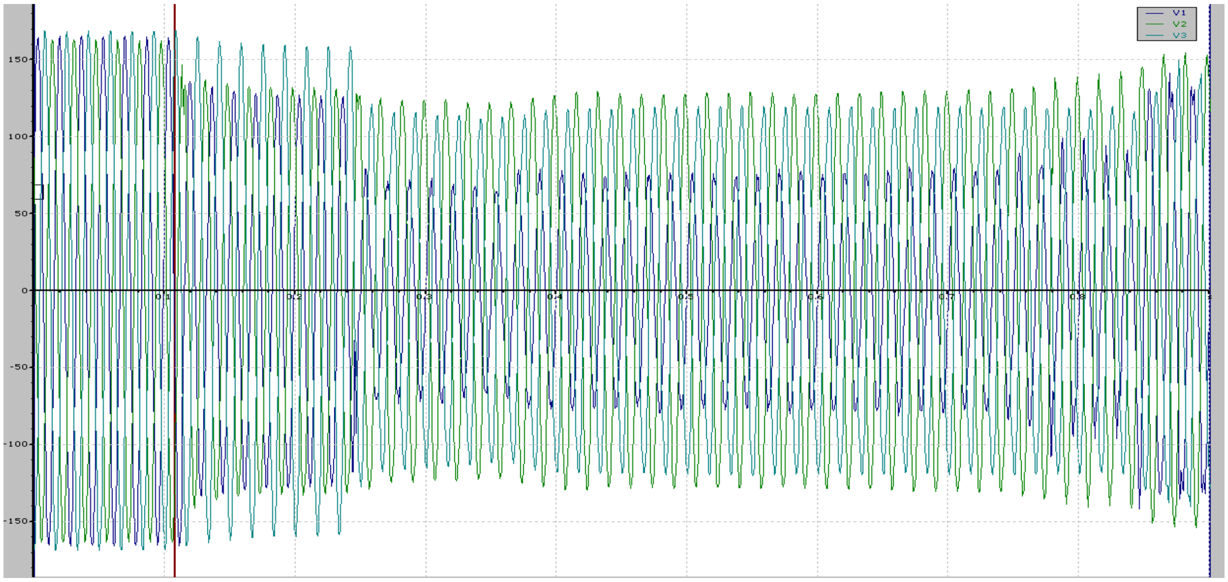
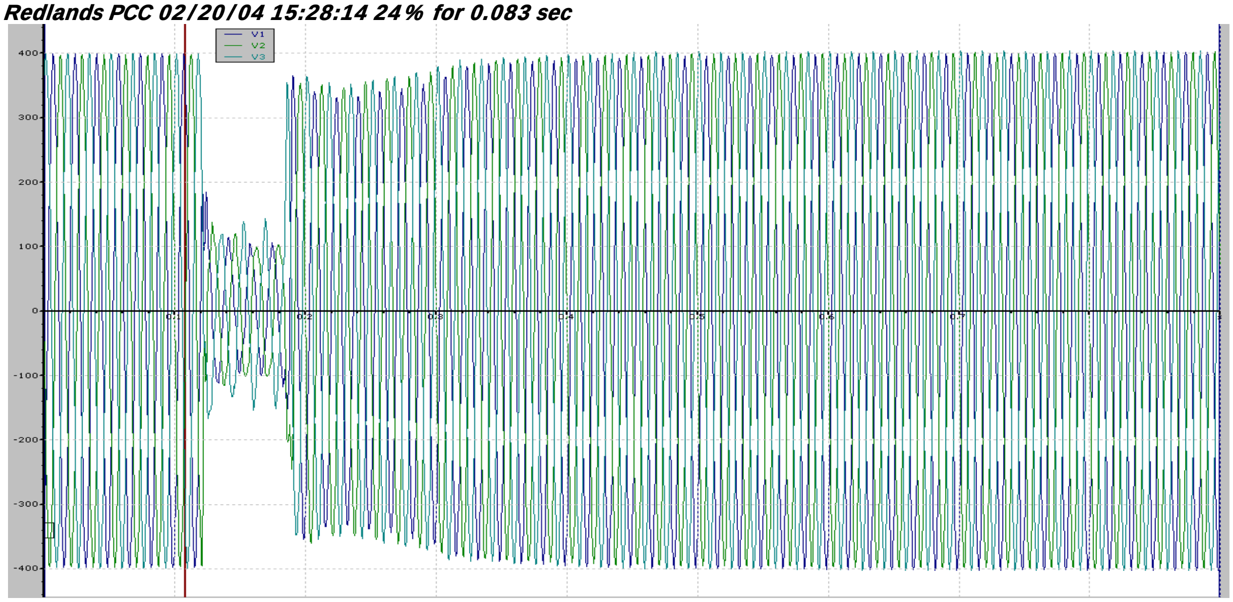


FIGURE 3-8: REDLANDS 02/20/04 EVENTS

Redlands PCC 02/20/04 15:28:14 24% for 0.083 sec



Redlands NGMT 02/20/04 15:28:28 24% for 0.083 sec

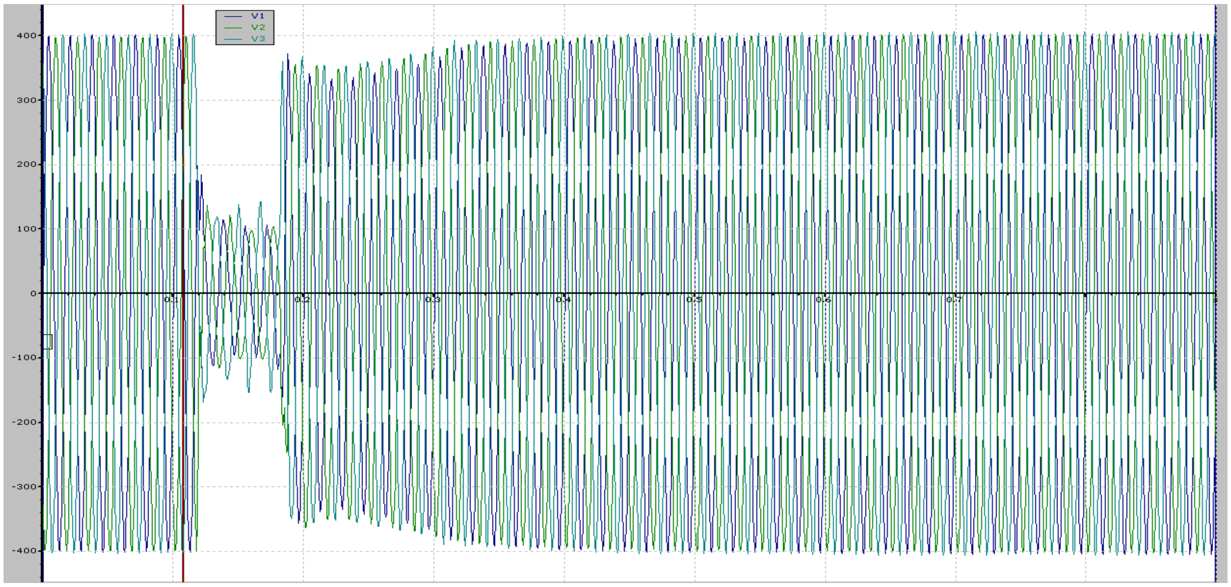
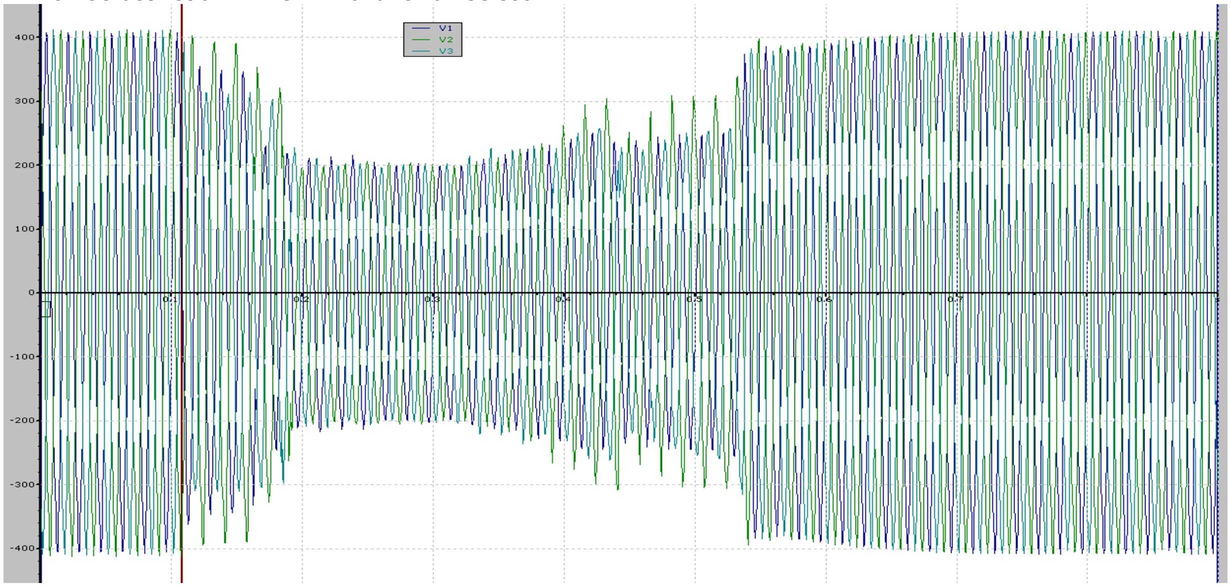

V1
V2
V3
400
300
200
100
0
-100
-200
-300
-400
0.1
0.2
0.3
0.4
0.5
0.6
0.7

FIGURE 3-9: IRVINE 03/15/04 EVENTS

Irvine PCC 03/15/04 17:13:27 49% for 0.433 sec



Irvine FC 03/15/04 17:13:26 49% for 0.524 sec

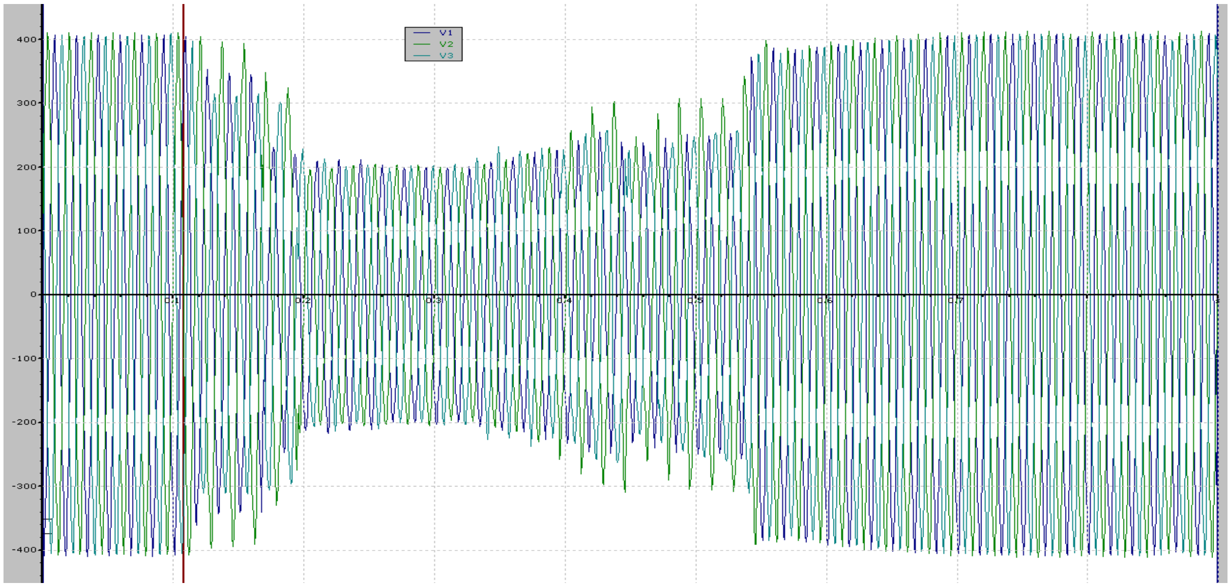
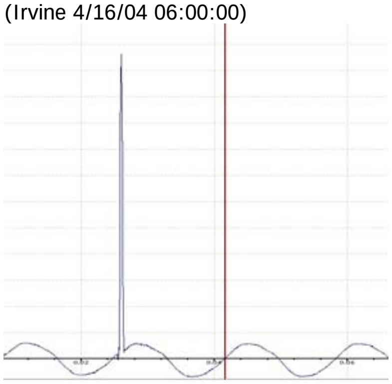
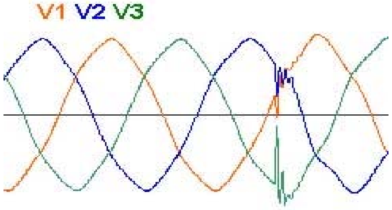


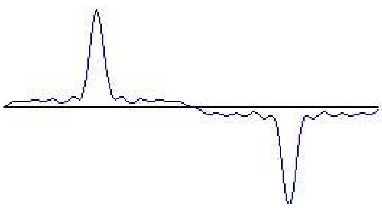
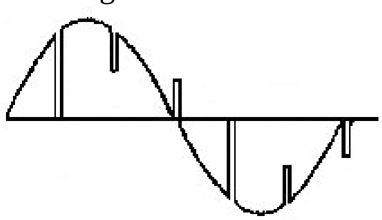
TABLE 3-8: IMPULSIVE AND OSCILLATORY TRANSIENTS

Power Quality Disturbance	Classification	Probable Cause	Equipment Impacts
Impulsive [31] (Irvine 4/16/04 06:00:00) 	1. A sudden and short duration disturbance by a very rapid change in the stead-state condition of voltage, current, or both, that is unidirectional in polarity. 2. Frequency Range: >5 kHz (High Frequency) 3. Duration: 30-200 uSec.	Lightning	1. Transformer failures 2. Arrester failures 3. Customer equipment damage due to low-side surges
Oscillatory [32] (Irvine 2/1/04 07:51:16) 	A temporary rapid fluctuation in the steady-state condition of voltage, current, or both, that includes positive and negative polarity values		
Low Frequency	<500 Hz, <30 cycles	Capacitor Switching	Tripping of ASDs and other sensitive equipment
Medium Frequency	500 Hz -= 2 kHz, <3cycles	1. Traveling waves from lightning impulses 2. Capacitor and circuit switching transients	Failure of customer equipment
High Frequency	>2 kHz, < 0.5 cycles	1. Switching on secondary systems 2. Lightning-induced ringing 3. Local ferroresonance	1. Radiated noise may disrupt sensitive electronic equipment 2. High rate of rise oscillations may cause low voltage power supplies to fail

[31] Data analysis and research of the waveforms for Impulsive Transients found only one occurrence, which was the lighting strike at the Los Angeles site. This event did cause equipment failure with a blown SCR.

[32] Data analysis and research of the waveforms for Oscillatory Transients revels that this the typical type of event and it has been recorded at all sites..

TABLE 3-9: WAVEFORM DISTORTION

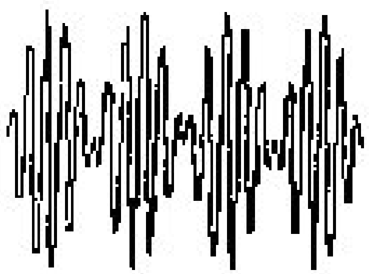
Power Quality Disturbance	Classification	Probable Cause	Equipment Impacts
Harmonics [33] 	Nonlinear loads, such as power electronic equipment, produce non-sinusoidal current waveforms when energized with a sinusoidal voltage. They inject currents at harmonic (integer multiple of the fundamental frequency) frequencies into the system. Harmonic currents, and the voltage distortion they create as they flow through the system impedance	Nonlinear loads	1. Misoperation of sensitive equipment 2. Capacitor failure or fuse blowing 3. Telephone interference
Notching [34] 	Periodic voltage disturbance caused by the normal operation of power electronics devices when current is commutated from one phase to another	Normal operation of electronic equipment	1. Misoperation of equipment 2. Equipment failure
Noise [35]	Any unwanted electrical signals with broadband spectral content lower than 200 kHz superimposed upon the power system voltage or current in phase conductors, or found on neutral conductors or signal lines	1. Improper grounding 2. Normal operation of electrical equipment 3. Arcing devices 4. Switching power supplies	Disturbing electronic devices such as microcomputer and programmable controllers

[33] Data analysis and research of the waveforms did not find any distorted waveforms because of Harmonics. As documented in Table 1-2, all of the THD Indices were below the 5% limit of IEEE Std. 519-1992.

[34] Data analysis and research of the waveforms for Notching did not find any Notching events.

[35] Data analysis and research of the waveforms for Oscillatory Transients revels that this the typical type of event and it has been recorded at all sites..

TABLE 3-10: VOLTAGE FLUCTUATION

Power Quality Disturbance	Classification	Probable Cause	Equipment Impacts
Voltage Fluctuation [36] **(Flicker)** 	The impact of voltage fluctuation on lamps such that they are perceived to flicker by the human eye. This is due to loads, which exhibit continuous, rapid variations in the load current, particularly the reactive component.	1. Arc furnaces 2. Intermittent loads	1. Lighting flicker 2. Misoperation of sensitive loads

[36] Data analysis and research of the waveforms for Voltage Fluctuations was accomplished via the ION EN50160 Report, which includes Flicker as a key element. EN50160 is a general power quality standard used by energy suppliers and energy consumers in European countries. After several revisions for the Monitor Framework, all monitors were compliant with the Flicker requirements.
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4 RMS Voltage Variations: Results and Observations (DG ON & OFF)

4.1 Introduction

Voltage sags and momentary interruptions, which are considered rms voltage variations by IEEE Std. 1159-1995, are often the most important power quality concerns for customers. In general, customers understand that interruptions cannot be completely prevented on the power system. However, they are often less tolerant when their equipment misoperates due to momentary disturbances that can be much more frequent than complete outages. These conditions are characterized by short duration changes in the rms voltage magnitude supplied to the customer. The impact on the customer depends on the voltage magnitude during the disturbance, the duration of the disturbance, and the sensitivity of the end-use equipment.

Voltage sags and interruptions are inevitable on the power system, and are generally caused by faults on the utility system. It is impossible to completely eliminate the occurrence of faults on the distribution system. Storms are the most frequent causes of faults in most areas of the country. Even preliminary monitoring results from this project clearly indicated that a weather storm or firestorm passing through an area could result in dozens of major and minor power quality variations.

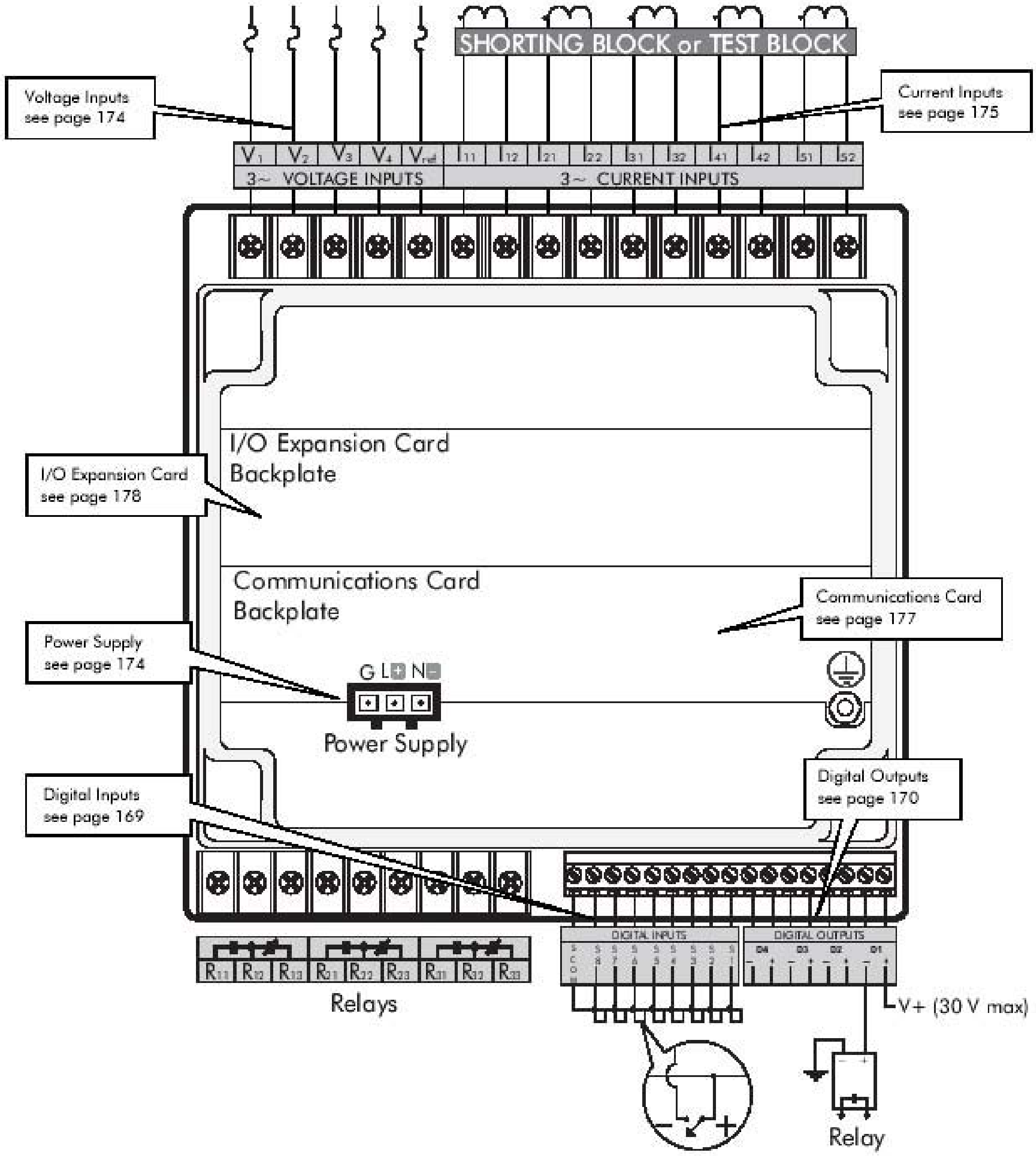
On the utility system, protection schemes are designed to limit damage caused by unusual events such as faults caused by lightning strikes, and to localize the impact of such events to the smallest number of customers. This is often accomplished with overcurrent protection devices, such as reclosers, sectionalizers, and fuses.

Voltage sags are characterized by the magnitude of the voltage during the fault and the duration of the event. Figure 1-9 and Figure 1-10 illustrate voltage sags.

4.2 Characterization of Voltage Sags

The monitoring instrument chosen for the FOCUS-II monitoring system is the Power Measurement ION 7600 or ION 8500. Its sampling rate is 256 samples per cycle for voltage and current. It has eight input channels; four are devoted to voltage and four to current, covering all three phases and the neutral. RMS voltage and current are computed by integrating the 256 sampled points. The ION 7600 & ION 8500 are capable of recording measurements that are scheduled (i.e., steady-state waveform sampling) or are triggered by a power quality disturbance.

FIGURE 4-1: ION 7600 BACK PANEL AND CONNECTIONS



The voltage dip is based on half-cycle RMS measurements. The duration of the dip corresponds to the period during which the RMS value remains less than 90% of the nominal voltage. The depth of the dip is defined as the difference (expressed in % of nominal voltage) between the minimum RMS voltage over the course of the dip and the nominal voltage. Interruption detection is based on half-cycle RMS measurements. The duration of the interruption corresponds to the period during which the RMS value remains less than 1% of the nominal voltage.

4.3 Statistical Distributions of Voltage Sags and Interruptions

The results for sag and interruption magnitude rate for the events recorded by the FOCUS-II Monitors between 8/26/02 to 10/31/04 are summarized in Figure 4-2. This analysis represents the raw analysis while the temporal aggregation analysis is presented in Table 4-1. The results represent all project monitors. Each column represents the rate of sags in which the minimum voltage fell into a particular range. For example, Figure 4-2 tells us that the average monitor experienced 39.75 incidents per 365 days (red bar) where the voltage was less than 90% (x-axis) of the site's base voltage and this represents 100% (blue line) of the events,

If we consider the left-most columns of the histogram (0 to 10 % red bar), then we can say that the typical FOCUS-II monitor experienced an average of 0.06 voltage interruption incidents per 365 days. For this report, an interruption event is defined as an rms voltage variation in which there was less than 10% of the declared nominal voltage remaining, which agrees with the definition of an interruption provided by IEEE Std. 1159-1995.

The other columns represent voltage sags in which the minimum voltage fell to between 0.1 and 0.9 per unit.

Figure 4-3 provides the Sag & Interruption Rate Magnitude Histogram for the PCC monitors and DG monitors while Figure 4-4 provides the data for the individual DG monitors by technology.

FIGURE 4-2: SAG & INTERRUPTION RATE MAGNITUDE HISTOGRAM (ALL MONITORS)

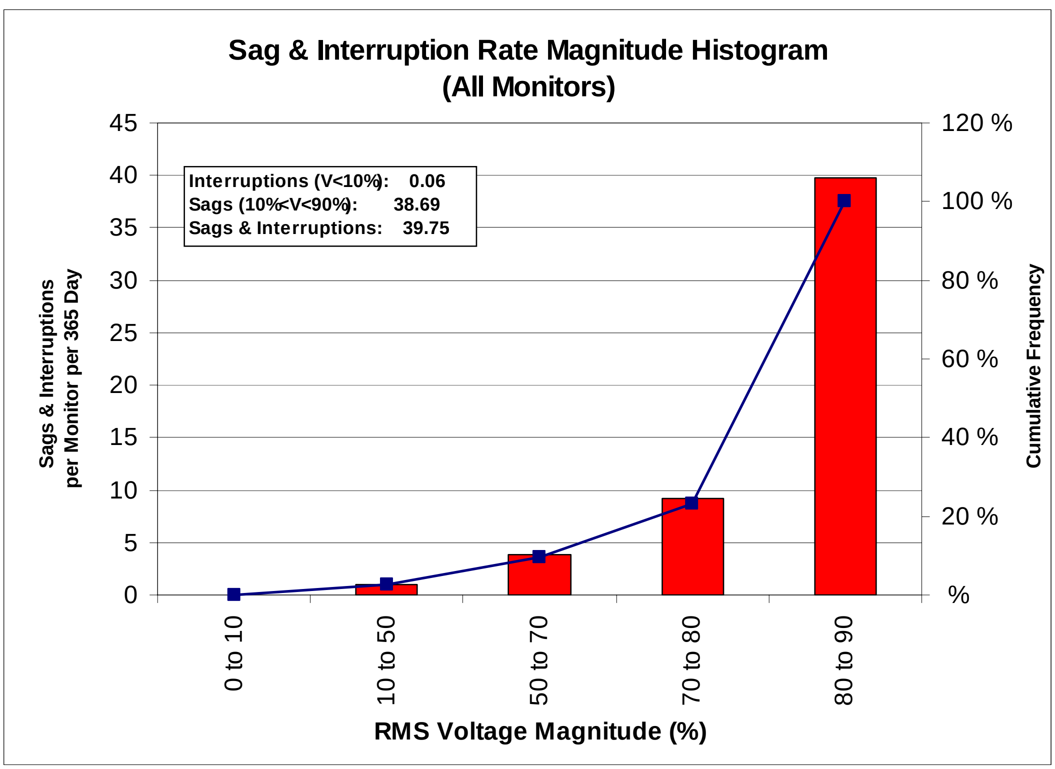


FIGURE 4-3: SAG & INTERRUPTION RATE MAGNITUDE HISTOGRAM (DG & PCC MONITORS)

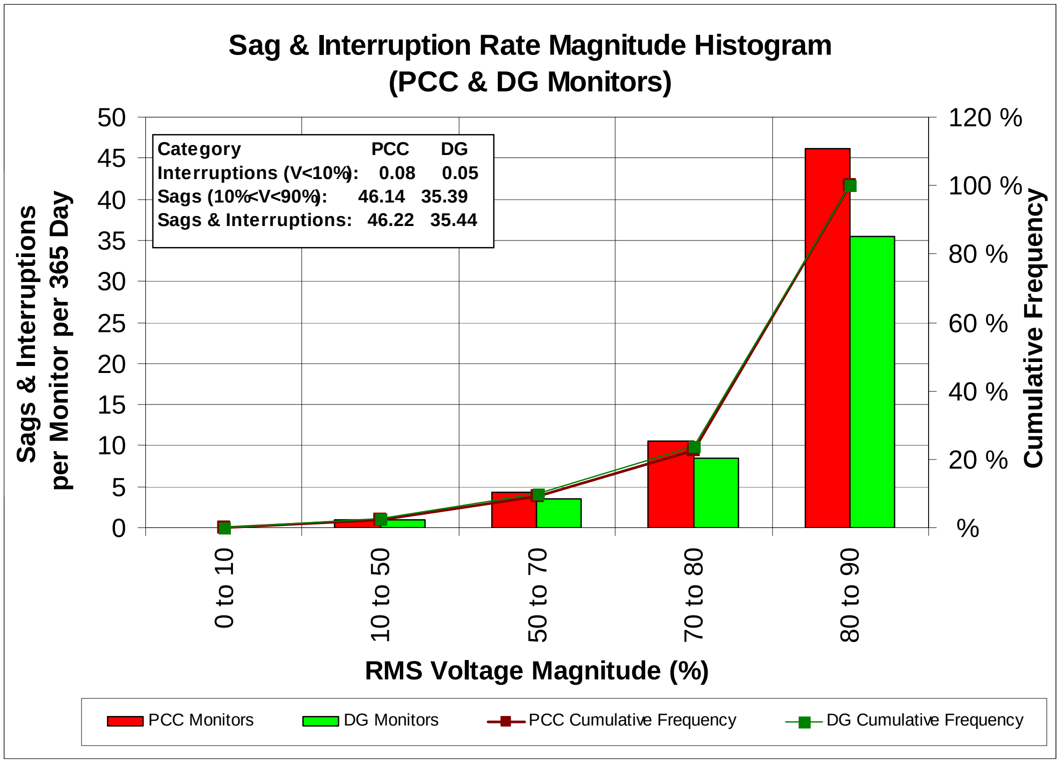
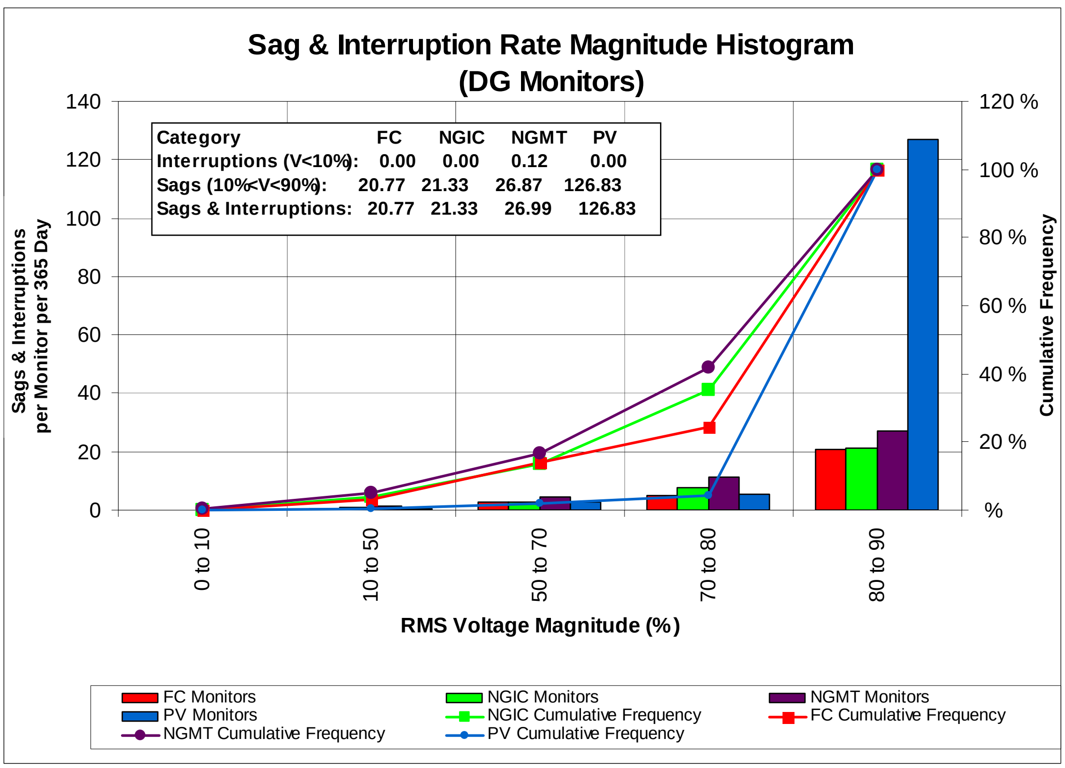


FIGURE 4-4: SAG & INTERRUPTION RATE DURATION HISTOGRAM (DG MONITORS)



4.4 SARFI: Sag and Interruption Rates

While Figure 4-2, Figure 4-3 and Figure 4-4 provide valuable information regarding average sag and interruption rates, an understanding of the range on values measured at different sites is also useful. To plot a range of values, we need to identify just one value of interest. If we consider just the incidents in which the minimum voltage fell below 0.90 per unit and temporally aggregate them with a 60-second period, then we can compute an index known as $SARFI_{90}$, which is a special case of $SARFI_{x.}$

A power system event occurrence is the real-world incident that triggers any number of measurements to be recorded by the ION 7600 or ION 8500. Examples include two conductors being blown together, a tree branch being brushed against one or more lines, lightning strikes, or the unfortunate act of an animal that creates an arc between part of the system and a grounded object. Other power system occurrences are planned, such as capacitor switching, and voltage reductions. We attempt to create a one-to-one relationship between temporally aggregated data and power system occurrences when computing system performance indices. For this section of the report, measurements were aggregated over one-minute intervals. The objective of temporal aggregation is to collect all measurements taken by the PCC monitor or the DG monitor that were due to the same power system occurrence, and identify them as one event. So we look at the PCC Monitor and the DG Monitor and see if an individual incident is the same. Then we compare the time stamp to find the source of the event and if they were within 60 seconds. Once that was determined, the SARFI analysis was completed. Table 4-1 includes the unaggregated SARFI analysis for comparison with the event-aggregated totals. A summary of the detail results for aggregated analysis in Appendix C1 to C7.

TABLE 4-1: TEMPORAL AGGREGATION (TA) OF ANNUAL SARFI INDICES.

	Monitor Location	$SARFI_{10}$	$SARFI_{50}$	$SARFI_{70}$	$SARFI_{80}$	$SARFI_{90}$
Initial SARFI Analysis	**Project Average**	0.06	1.01	3.88	9.24	39.75
	PCC Average	0.08	1.03	4.32	10.48	46.22
	DG Average	0.05	0.99	3.58	8.42	35.44
	Fuel Cell Average	0.00	0.61	2.89	5.08	20.77
	NGMT Average	0.12	1.37	4.54	11.28	26.99
	NGIC Average	0.00	0.86	2.90	7.51	21.33
	PV Average	0.00	0.50	2.50	5.49	126.83
Temporal Aggregation SARFI Analysis	**Project Average**	0.03	0.41	1.67	3.59	12.29
	PCC Average	0.08	0.67	2.83	5.33	13.93
	DG Average	0.00	0.23	0.89	2.42	11.20
	Fuel Cell Average	0.00	0.23	0.70	1.16	4.81
	NGMT Average	0.00	0.00	0.71	2.62	6.55
	NGIC Average	0.00	0.56	1.17	3.02	9.46
	PV Average	0.00	0.49	1.47	2.94	46.07

As outlined in Section 1.4 and using that method to calculate the SARFI Indices, we can develop a summary, which is documented in Appendix C (C.8 to C.14). Appendix C provides a complete synopsis of SARFI Indices by month for PCC & DG along with each type of technology (FC, NGIC, NGMT & PV) included in the project. Additional methods of presenting the data can be found on the Website.

4.5 Monitoring SARFI Rates

In Table 4-1, we present a summary of the indices for $SARFI_{90}$, $SARFI_{70}$, $SARFI_{50}$, and $SARFI_{10}$ for each of the FOCUS-II Monitors. The results are sorted in descending order based on the $SARFI_{90}$ value. Two PCC monitors—at South Gate and Redlands—exhibit the highest rate of $SARFI_{90}$ rms voltage variations, recording 46.07 and 24.25 short-duration rms voltage variations respectively with a voltage drop below 0.90 per unit per 365 days. The average value for the $SARFI_{90}$, $SARFI_{80}$, $SARFI_{70}$, $SARFI_{50}$, $SARFI_{10}$ (sag) and $SARFI_{100}$ (swell) rates is given at the bottom of Table 4-2and is compared to the Edison DPQ Project Service Entrance averages for the same indices.

TABLE 4-2: AVERAGE EVENTS PER YEAR BY SARFI TYPE – ALL MONITORS

Monitor Location	$SARFI_{10}$	$SARFI_{50}$	$SARFI_{70}$	$SARFI_{80}$	$SARFI_{90}$	$SARFI_{100}$
South Gate PV	0.00	0.49	1.47	2.94	46.07	0.49
Redlands PCC	0.46	2.75	7.78	16.01	24.25	0.00
Sunnyvale PCC	0.00	0.00	2.58	3.87	20.00	0.00
South Gate PCC	0.00	0.00	0.98	2.45	16.17	0.00
Redlands NGMT	0.00	0.00	1.37	6.86	16.01	0.00
San Diego PCC	0.00	0.56	2.81	5.62	12.36	48.86
Sunnyvale NGIC	0.00	0.00	0.65	3.23	11.61	0.00
Irvine PCC	0.00	0.00	1.40	1.86	7.91	0.00
Irvine FC	0.00	0.47	1.40	2.33	7.44	0.00
San Diego NGIC	0.00	1.12	1.68	2.81	7.30	37.07
Los Angeles NGMT1	0.00	0.00	0.73	1.45	3.63	0.73
Los Angeles NGMT2	0.00	0.00	0.73	1.45	3.63	0.73
Los Angeles NGMT3	0.00	0.00	0.00	0.73	2.91	3.63
Los Angeles PCC	0.00	0.73	1.45	2.18	2.91	0.00
Los Angeles FC	0.00	0.00	0.00	0.00	2.18	1.45
SARFIx Totals	0.03	0.41	1.67	3.59	12.29	6.20
SCE Study Average[37]	**1.48**	**4.93**	**12.01**	**21.75**	**47.42**	**n/a**

4.6 SARFI Rates by Month

In Figure 4-5, we present a trend of monitors $SARFI_{90}$, $SARFI_{70}$, $SARFI_{50}$, and $SARFI_{10}$ values for each month.

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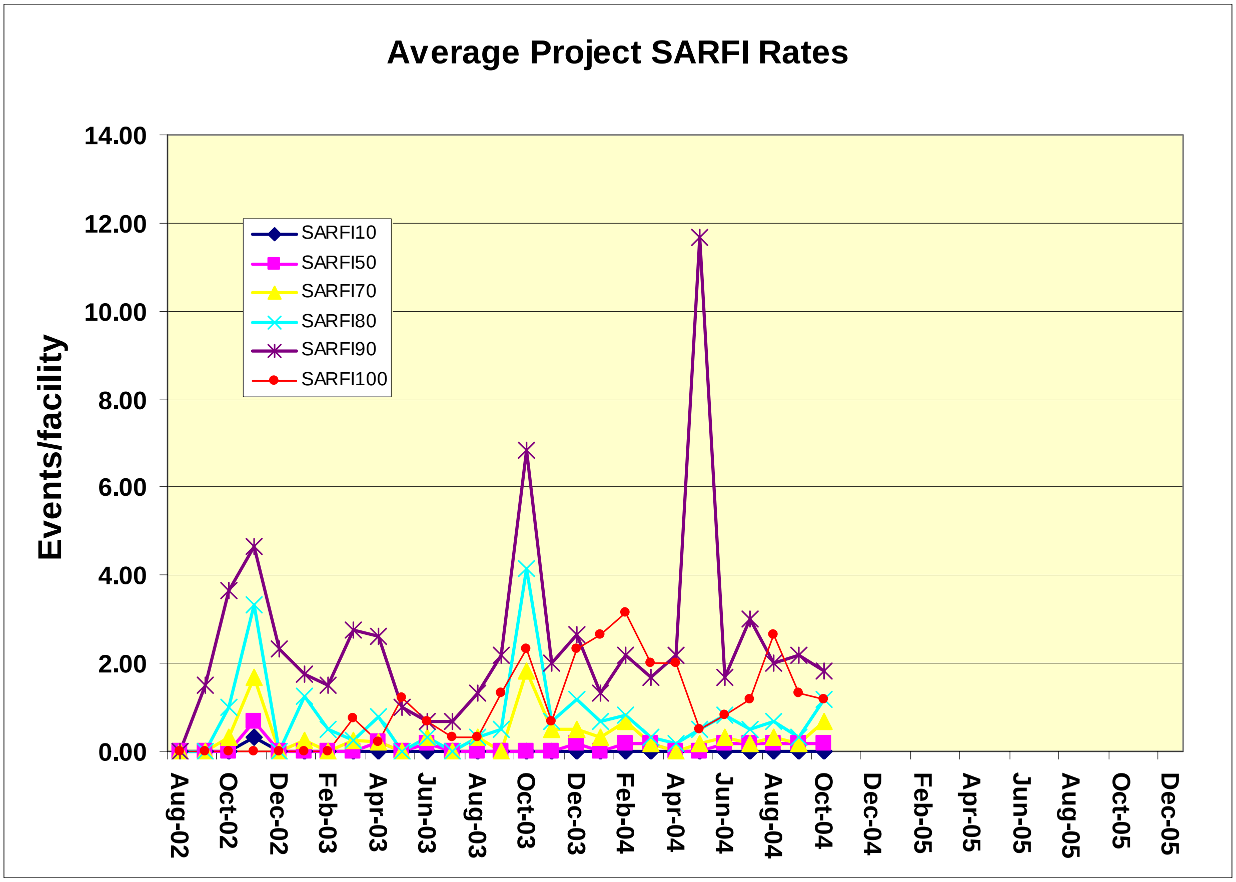
[37] Electrotek Concepts & Southern California Edison, "Power Quality Monitoring System: Final Report for Power Quality Data Collected at Southern California Edison from 7/1/97 to 7/1/99", EPRI Contract Number WO7114-02, Electrotek Project Number 1054-0001, December 20, 1999.

FIGURE 4-5: SARFI RATES BY MONTH



- November 2002 show a large jump in the rate of voltage sags (14 $SARFI_{90}$ events). Twelve of these events (5 on 11/8/02, 1 on 11/15/02, 3 on 11/25/02, 2 on 11/26/02 & 1 on 11/29) occurred at the Redlands site. These events are unexplained but might be related to a Santa Ana condition, which occurred during this month. Santa Ana's have tendency to result high winds which are generally dry hot winds that blow from the east or northeast (offshore). These winds occur below the passes and canyons of the coastal ranges of Southern California and in the Los Angeles basin. Santa Ana winds often blow with exceptional speed in the Santa Ana Canyon. As a result, it is not uncommon for power poles to break or conductors swaying in the wind resulting in phase to phase shorting conditions.
- The rise in $SARFI_{90}$ events in March 2003 (11 $SARFI_{90}$ events) is due in part by the Irvine site where 3 events occurred. When these events are disaggregated from the 60-second event windows, it is interesting to note that 9 of the 14 sub-events occurred at shutdown of the Fuel Cell and the events were recorded first on the PCC monitor and then the FC monitor; however, each of the 3 primary events came from the FC. This more complex interaction may be attributable to the fact that just prior to shutdown; the Fuel Cell was exporting about 14 kW.
- In late October 2003, Southern California was hit with one of the largest fire storms in recorded history and was the likely reason for the large number of events seen at Redlands (17 $SARFI_{90}$ events) from 10/24/03 through 10/29/03. Several large fires

burned in San Diego, and the San Diego facility too experienced in increase in $SARFI_{70}$, $SARFI_{80}$, and $SARFI_{90}$ events, with 3, 5, and 10 events respectively.

- In October and November, the San Diego facility also experienced an increase in $SARFI_{100}$ swell events, with the monitors registering 11 events at the PCC and 3 events at the DG. The increased incidence of swells on the distribution system may also be related to the effects of the San Diego fires. With the exception of October and November 2003, an increase in $SARFI_{100}$ events appears to be unrelated to increases in the number of sags.
- The cause of the spike in February-2003 and March 2004 is unknown but is mainly recorded at Redlands site. Since the Capstone Microturbines at Redlands were not installed at the time of these events, we do know that these events originated on the distribution system.
- The cause of the spike in May 2004 is unknown but is mainly recorded at South Gate site. When the site was visited, it was found that the lock on monitoring enclosure had been cut off and this may explain the unusual increase in events at this PV site.

4.7 Event Duration Analysis

Figure 4-6 illustrates the results for sag and interruption duration rate analysis, using one-minute temporal aggregation, for the events recorded for all monitors. Figure 4-7 provides the same data for PCC monitors while Figure 4-8 contains the data for the DG monitors. The results for sag and interruption duration analysis for the events recorded by the FOCUS-II Monitors between 8/26/02 to 10/31/04 are summarized in these Figures. Each column represents the number of sags in which the minimum voltage fell below 90 pu. It then correlates these events with the duration of the event to obtain an appreciation of the severity of the event. For example, Figure 4-6 (all monitors) tells us that 42 incidents occurred with duration of 1 cycle or less and this represents 12% of the sag events. The red bar is the number of events in each duration category and the blue line is the accumulative frequency (percent) of the events.

FIGURE 4-6: SAG & INTERRUPTION RATE MAGNITUDE HISTOGRAM (ALL MONITORS)

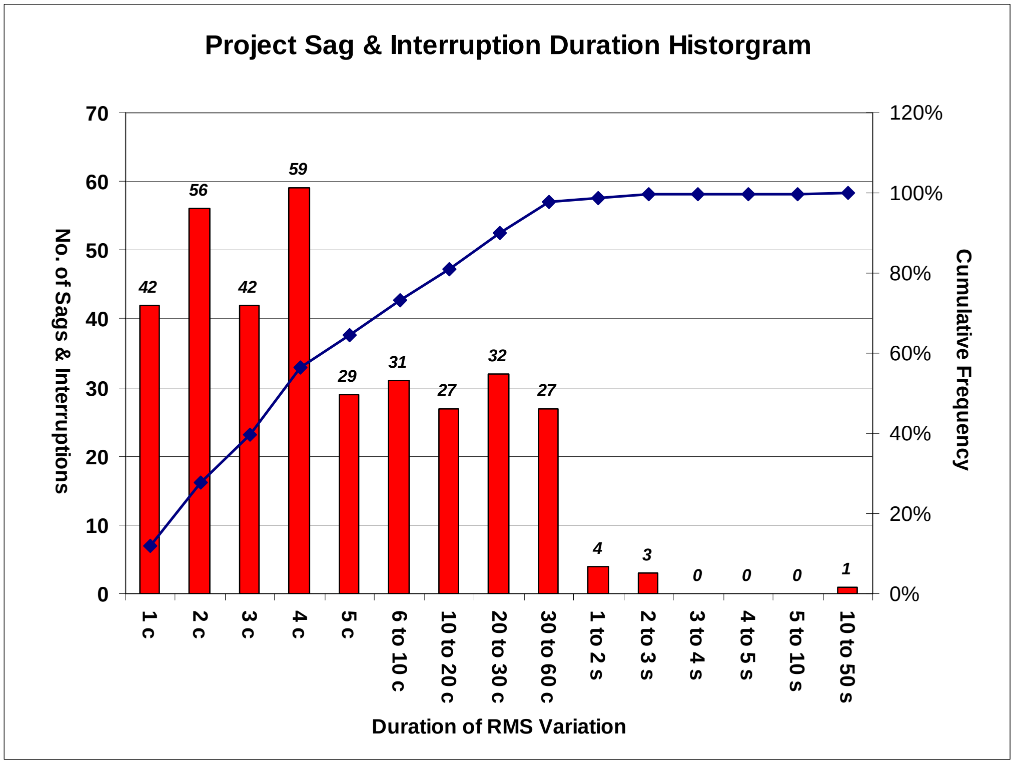


FIGURE 4-7: SAG & INTERRUPTION RATE MAGNITUDE HISTOGRAM (PCC & DG)

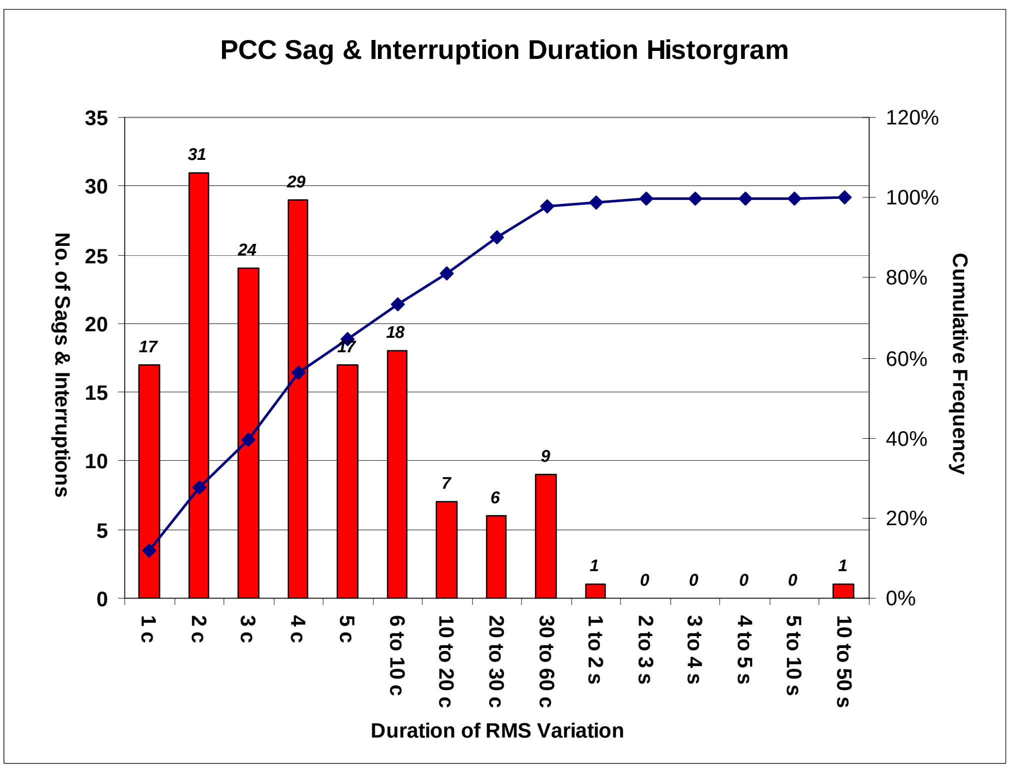


FIGURE 4-8: SAG & INTERRUPTION RATE MAGNITUDE HISTOGRAM (FC, IC, MT & PV)

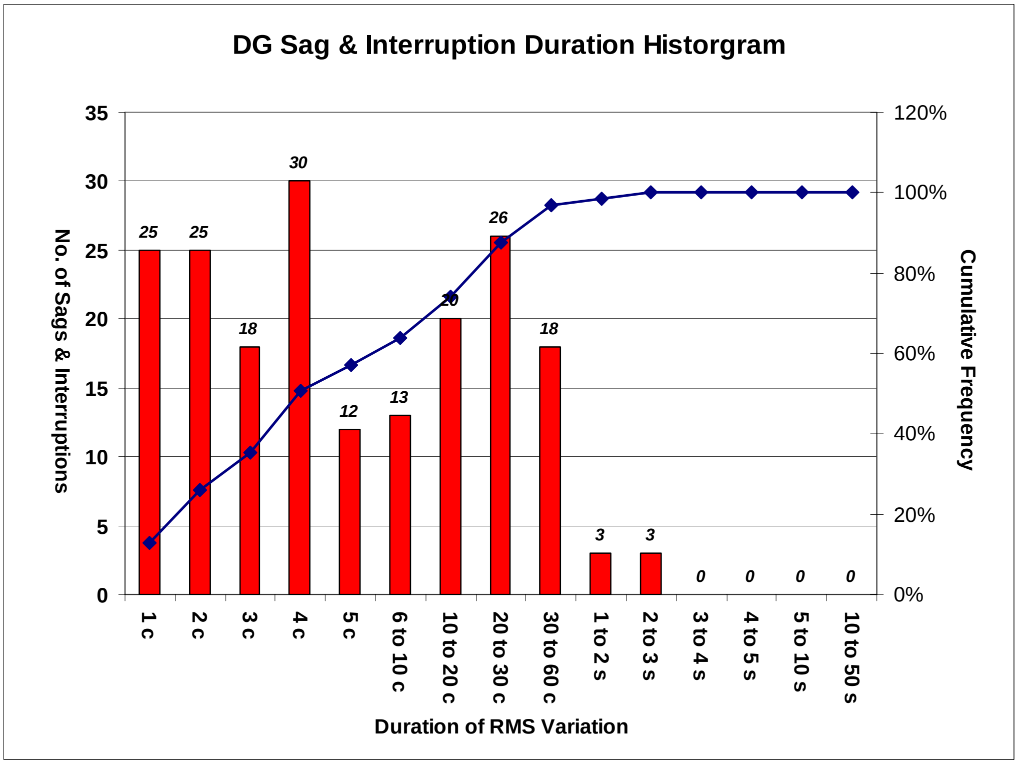
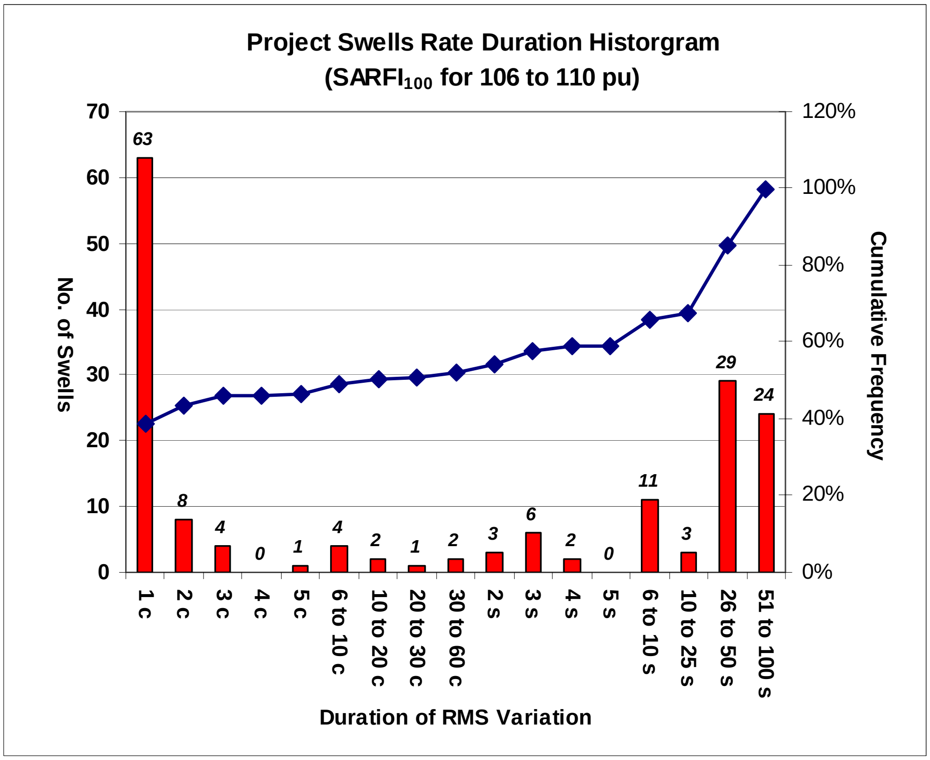


Figure 4-10 provides the swell duration rate analysis. Although the FOCUS-II monitors recorded many voltage swells events, none of these events exceeded the 1.1 pu to classify them as $SARFI_{110,}$ $SARFI_{120}$ or $SARFI_{140}$. A large number of swell events occurred, though, that were above 106% which is the standard setup trigger for the program monitors. For this reason, we have introduced a SARFIx index of 100 to capture these events from 106% (monitor trigger) to 110% (start of next SARFI Index).

FIGURE 4-9: SWELL RATE MAGNITUDE DURATION HISTOGRAM



4.8 Magnitude-Duration Analysis

If we combine Figure 4-5 and Figure 4-6 into one chart analyzing the events as a function of minimum voltage magnitude and event duration, we obtain the three-dimensional column chart presented in Figure 4-10. The values for each of the columns of Figure 4-10 are also provided in Appendix C. The data provided is the Magnitude Duration Event Log of individual rms voltage variations recorded by the FOCUS-II monitoring system during the period from 8/26/02 to 10/31/04. The measurements were subjected to Temporal Aggregation using a 60-second time interval.

The same analysis is provided for the swell events and included in Figure 4-11

FIGURE 4-10: SAG AND INTERRUPTION RATE MAGNITUDE-DURATION HISTOGRAM

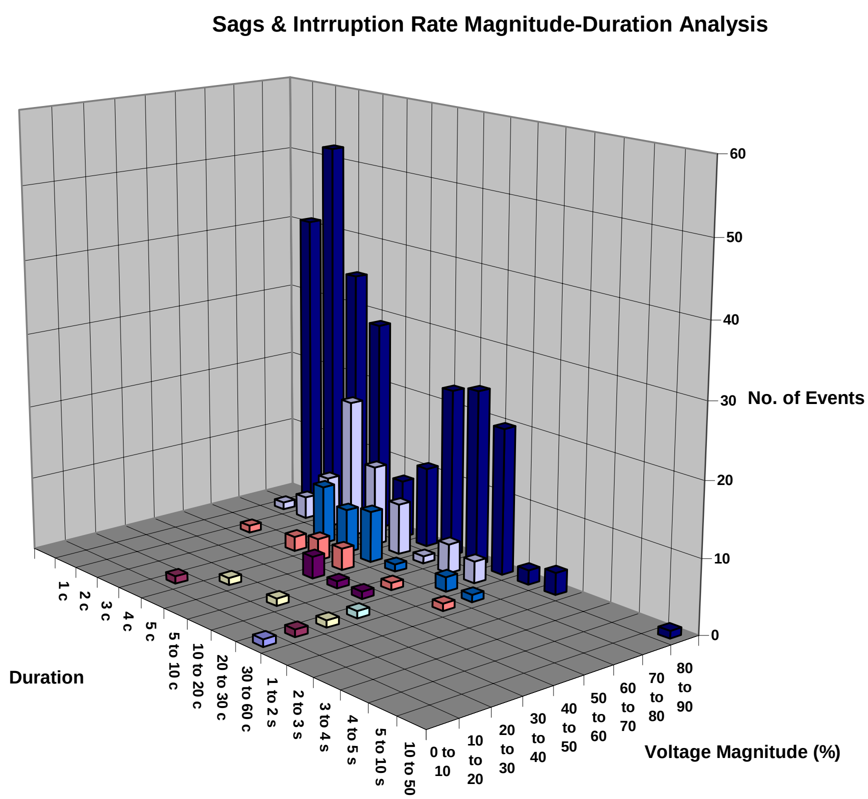
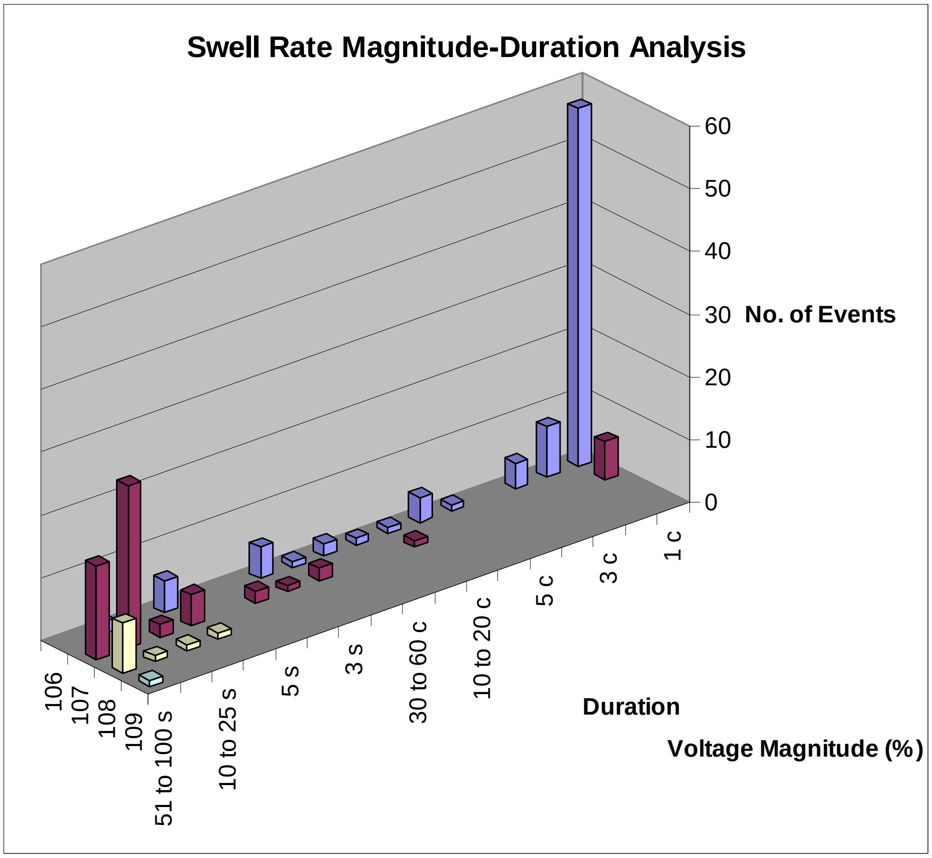


FIGURE 4-11: SWELL RATE MAGNITUDE-DURATION ANALYSIS



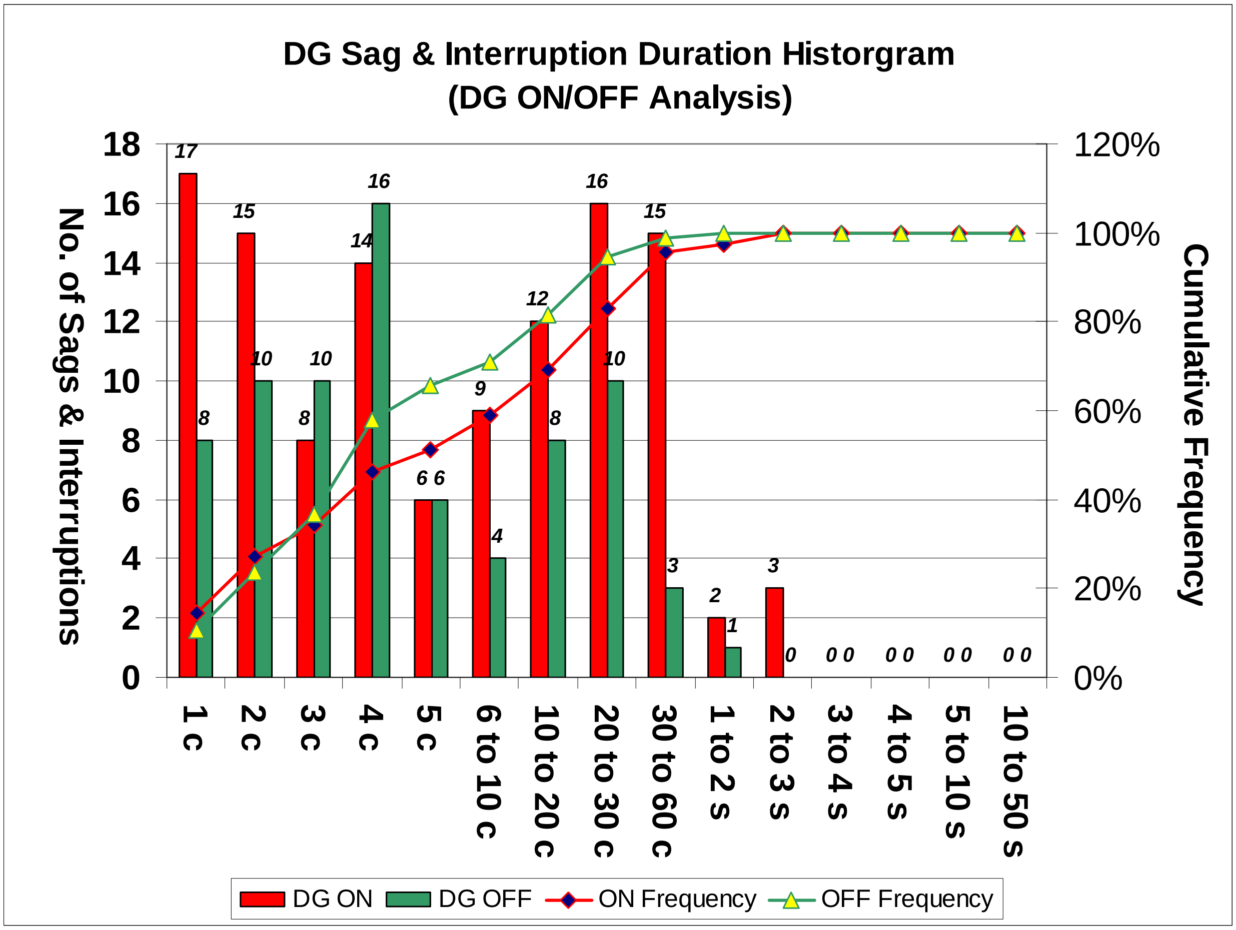
4.9 DG ON/OFF Analysis

The study did look at the operational status of the DG and we find the following operational percentage for the period July 02 through November 04.

Operational Percentage	2002	2003	2004	Average
Irvine – FC	92.14	91.56	75.60	87.87
Los Angeles – FC		74.75	56.42	64.83
Los Angeles – NGMT1		86.00	94.77	90.75
Los Angeles – NGMT2		25.95	28.23	28.10
Los Angeles – NGMT3		85.48	100.00	93.34
Redlands – NGMT	0.00	0.00	0.00	0.00
San Diego – NGIC		69.69	35.95	53.85
South Gate – PV	38.39	45.20	46.05	44.86
Sunnyvale – NGIC		37.68	10.79	25.18

Looking at the sag disturbances (Figure 4-12) for the DG during the ON and OFF periods did not establish any trends one way or the other which could be used to draw some conclusion. It was also noted that about 10 percent of the sag disturbances occurred during startup or shutdown of the DG.

FIGURE 4-12: DG ON/OFF ANALYSIS



The Harmonic Distortion Analysis (SATHD) was the same for both conditions.

5 Harmonic Distortion: Results and Observations

5.1 What is Harmonic Distortion?

Like surfers, most electrical devices are looking for the perfect wave. For alternating current, perfection is defined by a sinusoidal (or sine) wave in which electrical voltage changes smoothly from positive polarity to negative and back again 60 times per second. Unfortunately, modern electronic equipment at customer sites is having a negative effect on the quality of this perfect wave. A variety of solid-state devices, including desktop computers and other microprocessor-based devices, create high levels of harmonic distortion. Although not perfect, the voltage signal produced by power system generators approximates a perfect sinusoid with a rather high degree of accuracy. Almost all load equipment connected to the electric power system has been designed to operate from a sinusoidal voltage source.

Harmonic distortion may or may not create a problem for a facility. A customer may have harmonics present, but experience no adverse effects. However, as harmonic levels increase, the likelihood of experiencing problems also increases. Typical problems include:

- Malfunctioning of microprocessor-based equipment;
- Overheating in neutral conductors. Transformers, induction motors or rotating machinery;
- Deterioration or failure of power factor correction capacitors or capacitor banks;
- Erratic operation of breakers and relays;
- Pronounced magnetic fields near transformers and switchgear;
- Telephone interference.

To make matters worse, harmonics can sometimes be transmitted from one facility back through the utility's equipment to neighboring businesses, especially if they share a common transformer. This means harmonics generated in a facility can stress utility equipment or cause problems in a neighbor's facility and vice versa. Electric utilities have recognized this problem and are adopting standards, like the Institute of Electrical and Electronics Engineers (IEEE) Standard 519 which defines allowable harmonic distortion at customer service entrances. This standard is designed to protect both businesses and utilities.

Harmonic distortion of the distribution system voltage originates with nonlinear devices on the power system. Nonlinear devices produce non-sinusoidal current waveforms when energized with a sinusoidal voltage. Examples of these devices include adjustable-speed drives (ASDs), switching power supplies (including computers and other office equipment), fluorescent lighting, battery chargers, saturated transformers, and arc furnaces. Nearly all of these are nonlinear and are shunt elements, the bulk of which are loads.

Harmonic distortion problems range in severity from nuisance tripping of customer end-use equipment to complete failure of very expensive utility and customer equipment. Fortunately, distribution system harmonic distortion levels are generally constrained within acceptable limits, such that neither customer processes nor utility equipment are affected.

Most power systems can absorb far more harmonic current than engineers might think. A large percentage of the problems occur when capacitors cause the system to be in resonance condition, thereby increasing the voltage distortion levels.

Harmonics have existed on electric power systems for many years. Recently, however, much more attention has been given to monitoring and analyzing the presence and effects of harmonics on utility and customer devices than in the past. This new concern is the result of significant increases in harmonic distortion on many electric power systems in the last fifteen to twenty years. Two factors contributing greatly to this trend are:

- **The increasing size and application of nonlinear equipment,** which produces the majority of harmonic distortion on distribution systems. Power electronic devices comprise a large part of this increase in nonlinear equipment. The percentage of electric power that passes through these devices is increasing because of the additional energy efficiencies and flexibility that they offer.
- **Increased application of utility and industrial capacitors** to increase the utilization of existing distribution system infrastructures. Utilities are installing an ever-increasing number of capacitors on transmission and distribution systems for voltage control and loss reduction. Additionally, utilities are encouraging customers, through their rate structures, to install power factor correction capacitors in order to obtain additional capacity from the existing distribution system equipment.

IEEE Std. 519-1992 provides a recommended practice for controlling harmonics on the power system. This standard divides the responsibility for controlling harmonics between the customers that have nonlinear loads generating harmonics, and the supplying utility that may have system characteristics that magnify the harmonics due to resonance. Customers need to limit the amount of harmonic current that is injected onto the utility system. Utilities need to make sure that the overall system voltage distortion is acceptable so that connected utility and customer equipment will not be impacted. The harmonic distortion levels measured in this project are compared with the recommended levels from IEEE Std. 519-1992 for reference.

5.2 Statistics of Voltage Total Harmonic Distortion

Both the ION 7600 & ION 8500 has the capability to record individual and total harmonic distortion up to the 63rd harmonic (127th using ION Enterprise software). Early in the FOCUS-II Project, Reflective Energies had Power Measurement develop a special harmonics report, which is used to analyze the data. This report queries the database, analyzes the data and generates a report with the following harmonic indices:

- SATHD (System Average Total Harmonic Distortion)
- STHD95 (System Total Harmonic Distortion below 95%)
- STHD99 (System Total Harmonic Distortion below 99%)

TABLE 5-1: TOTAL HARMONIC DISTORTION SUMMARY

Monitor Location	SATHD	$STHD_{95}$	$STHD_{99}$
Irvine PCC (Commercial Building)	3.51	4.13	4.33
Irvine FC (UTC PC25)	3.51	4.13	4.33
Los Angeles PCC (Commercial Building)	1.10	1.70	1.97
Los Angeles FC (Fuel Cell Energy DFC300)	1.11	1.70	1.97
Los Angeles NGMT1 (Capstone C30)	1.10	1.70	1.97
Los Angeles NGMT2 (Capstone C30)	1.10	1.70	1.97
Los Angeles NGMT3 (Capstone C60)	1.10	1.70	1.97
Redlands PCC (Medical Facility)	0.41	0.71	0.83
Redlands NGMT (Capstone C60)	0.41	0.71	0.83
San Diego PCC (Commercial Building)	1.06	1.65	1.91
San Diego NGIC (Hess 200 Microgen)	1.06	1.65	1.91
South Gate PCC (Convenience Store)	1.22	1.73	1.97
South Gate PV (BP 14 kW)	1.22	1.73	1.97
Sunnyvale PCC (Manufacturing Facility)	0.12	0.42	0.53
Sunnyvale NGIC (Waukesha 3000 kW)	1.37	1.52	1.58
Focus II Average	**1.34**	**1.83**	**2.04**
Edison Service Entrance Average [38]	**1.45**	**2.16**	**2.91**

Table 5-1 demonstrates that all of the FOCUS-II monitors are well within the 5% value specified by IEEE Std. 519-1992. It also compares favorably with the SCE DPQ Service Entrance Averages. None of the DGs in the monitoring sample generated harmonics that caused the voltage THD to exceed the 5% limit specified in IEEE Std. 519. The distribution system for all sites was well within the requirements of the Standard.

[38] Electrotek Concepts & Southern California Edison, "Power Quality Monitoring System: Final Report for Power Quality Data Collected at Southern California Edison from 7/1/97 to 7/1/99", EPRI Contract Number WO7114-02, Electrotek Project Number 1054-0001, December 20, 1999.

5.3 Study THD Indices

Appendix D presents a summary of the indices related to voltage total harmonic distortion for all monitors. No values exceeded the 5% limit recommended by IEEE Std. 1159-1992 and all Indices are well within the Benchmark established the EPRI DPQ and SCE DPQ Projects. This indicates that the DG is performing well and not distorting any of the waveforms.

6 Conclusions and Recommendations

6.1 Fulfillment of Project Objectives

The FOCUS-II Monitoring Project set out to achieve the following objectives, as formulated in the "DG Monitoring Guidelines"[39].

1. Select of twelve (12) monitoring sites, which provide a balance between DG technologies, interconnection technologies and technical complexity.
2. Select a monitoring instrumentation system.
3. Develop a Test Plan.
4. Install instrumentation at these sites, which takes measurements of the impact of the interconnection by the generator upon the distribution/transmission grid.
5. Monitor the instrumentation and create a database for analysis of the data.
6. Analyze the data, provide significant results to the Interconnection Workgroup and provide a final report.

With this completion of this Final Report, all objectives have been fulfilled as follows:

Objectives 1 & 4

"Monitoring Guidelines" plan was developed that addressed site selection criteria and monitoring equipment selection criteria and process. The Monitoring Guidelines are included as Appendix F. A total of 23 monitors were installed on 16 DGs (the last in construction) at 9 selected facilities each monitored on both sides of the Point of Common Coupling: One monitor on the utility-side of the PCC and one on the customer side at the DG. In total there are 9 monitors at the PCC and 14 monitors at the customer DG. Extra monitors provide monitoring coverage for Los Angeles, San Diego (Inductive) and , San Francisco sites that have multiple DG technologies. The following DG and generator technologies are included:

Qty	*Technology*	*Generator Interconnection*
1	14kW Photovoltaic (PV) array	Inverter
3	675kW PV array (244, 225 & 207)	Inverter ***(Pending)***
2	200kW Internal Combustion Engine (IC)	Synchronous
1	3000kW Internal Combustion Engine (IC)	Synchronous
2	140kW Internal Combustion Engine (IC)	Synchronous ***(Pending)***
2	Fuel Cells (FC)	Inverter
5	Microturbines (MT)	Synchronous/solid state

[39] See Attachment F.

Monitors cover not only DG impact on the distribution system, but also the distribution system effect on the DG.

The larger PV array is on a network system, and three microturbines and one fuel cell are on the same feeder that is also on a spot network system. The other systems are on radial feeders.

Objective 2

The Power Measurement ION 7600 and ION 8500 were selected and installed, with assistance from Power Measurement. See Section 1.1.5 for details.

Objective 3

The Monitoring Test Plan was completed and approved and is included in Appendix G[40].

Objective 4

See Objective 1.

Objective 5

Monitoring data is collected regularly from all monitoring sites and compiled into a database. Each month, a summary of all power quality events is published to the project website at www.dgmonitors.com.

Objective 6

This paper presents all data collected and analysis performed in the FOCUS-II Monitoring Project. Periodic reports and updates have been given to the Interconnection Working Group from the fall of 2002 to the present. Final conclusions of the Monitoring Project will be made available to the Interconnection Working Group.

6.2 Project Conclusions

The following conclusions may be made for the data analyzed from the FOCUS-II monitoring project:

- For the systems monitored, the impact of the DG upon the grid power quality was found to be very low. The impact of the grid upon DG was also very low. This was determined by comparing the impact with previous studies. While the sample was too small and the duration too short for a general conclusion, it provides some assurance that the current requirements and approval process for DG is conservative, and is adequately protecting the grid. Some of the bullets below elaborate on this finding.

[40] See Attachment G.

- The project approach of placing a minimum of two monitors at each site—one at the DG, and one on the utility side of the PCC—has yielded a significant advantage: it has made it possible to measure how many events originate on the distribution system and are propagated to the DG on the customer site and how many events originate at the customer site with DG and are propagated to the distribution system. It is therefore possible, based on this sample, to conclude about the relative effects the parallel systems (DG & distribution system) are having on each other.

- A total of 477 events were logged during the monitoring. Of these, there are 245 SARFI events originating on the DG side (178 Sags & 67 Swells); 232 SARFI events originating on the PCC (Utility) side (151 Sags & 81 Swells), distributed as follows::

Project	DG Sag Events	PCC Sag Events	DG Swell Events	PCC Swell Events
Irvine - Total	16	17	0	0
Los Angeles - Total	15	4	9	0
Redlands - Total	32	52	0	0
San Diego - Total	8	20	57	81
South Gate - Total	90	30	1	0
Sunnyvale - Total	17	28	0	0
All Facilities - TOTAL	178	151	67	81

None of these events (save one, see below) was of serious consequence.

- In the FOCUS-II sample of projects, it is clear from the above that, on average, 50% more events originate on the PCC (Utility) side than on the DG side. Southgate and Los Angeles are exceptions. If the FOCUS-II Monitoring Project is representative of DG installations in the state, it may be said that in general DG is having less effect on the grid than the grid is having on DG. The impact in either direction, however, is not very significant. The most significant power quality events recorded were natural phenomena: the lighting strike at the Los Angeles facility and the fires near Redlands and San Diego.

- There has been only one incidence of an interruption (voltage reduction greater than 90%)—at Redlands on 11/25/02 at 13:28:34, the voltage on the PCC side dropped to 9% pu for 0.734 sec. This is classified as a "momentary" event under IEEE 1159-1995. Because the voltage never dropped to 0%, and no temporary or long duration interruptions occurred, it is not possible to report any condition of "islanding",[41] or about the effectiveness of anti-islanding protection.

- The power quality monitors installed throughout California as part of project demonstrated a high level of availability with an average availability of over 99% from 8/26/02 to 10/31/04.

[41] Rule 21 defines Islanding as "A condition on [the utility's] Distribution System in which one or more Generating Facilities deliver power to Customers using a portion of [the utility's] Distribution System that is electrically isolated from the remainder of [the utility's] Distribution System."

- The frequency of events at the PCC was about one-third of the benchmarks created by EPRI and Edison. The average FOCUS-II PCC monitor experienced about 13.93 voltage sags and interruptions per 365 days. The average measured by EPRI's DPQ Project survey of 24 electric utility systems was about 54.63 voltage sags and interruptions. The average Edison service entrance monitor also experienced about 47.42 voltage sags per 365 days. The IEEE standard for such events is IEEE Std. 1159-1995 which defines monitoring of electric power quality of ac power systems, definitions of power quality terminology, impact of poor power quality on utility and customer equipment, and the measurement of electromagnetic phenomena are covered. IEEE standard 1366-2003 defines useful distribution reliability indices, and factors that affect their calculation, are also identified. This standard includes indices that are used today as well as ones that may be useful in the future.

- The frequency of events at the DG was less than the PCC. The average FOCUS-II DG monitor experienced about 11.20 voltage sags and interruptions per 365 days.

- The frequency of severe events was also low compared to the benchmark. The rate of very severe voltage sags and interruptions at the PCC was 0.67 events while the DG was 0.23 per 365 days (considering those voltage sags with voltage magnitudes below 0.50 per unit). For comparison, the severe $SARFI_{50}$ event frequency was 4.93 events in the SCE DPQ Study while the EPRI DPQ Study found a feeder average of 12.07 events per 365 days.

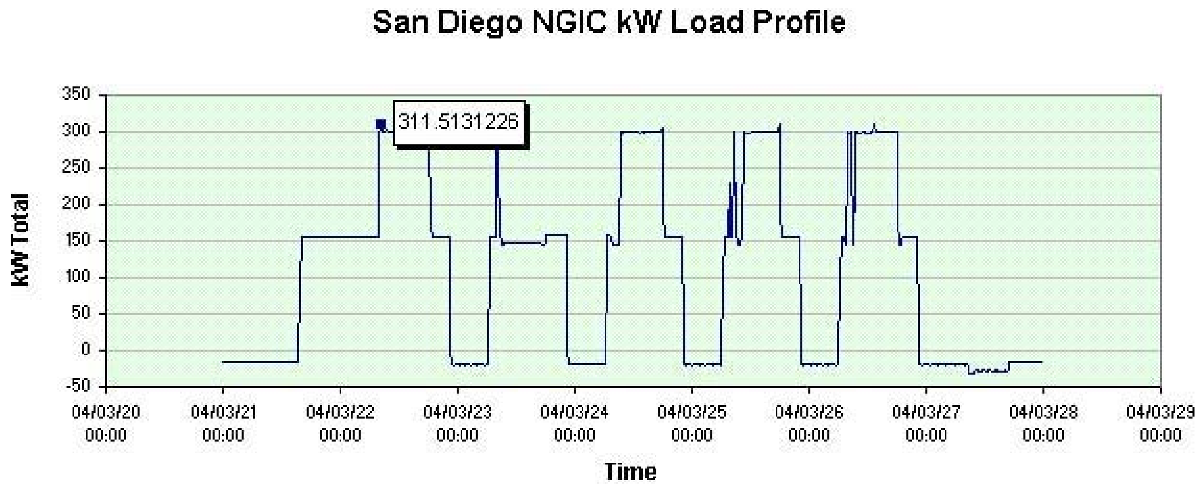
- The average value of voltage total harmonic distortion (THD_V) measured at the PCC was 1.30% and DG was 1.34% well with in the IEEE Std. 519-1992 requirements.

- All of the Power Quality Indices were lower than the EPRI's and Edison DPQ Projects indicating that the DG is not introducing any unwanted power quality events into the distribution system.

- Only the Irvine site with a Fuel Cell exported power and all power quality indices for that site were well within the Monitoring Project nominal values. This provides some comfort that exporting of small amounts of power may be acceptable, although much more data would be needed to provide assurance of this. Net Metering systems also allow minor export of power, and no serious consequences of such export have been reported.

- We found that DG is installed for various reasons and this dictates the operating mode. For instances, the San Diego site which is a commercial building has a program cycle for its two ICs. This site has two natural gas-fired Hess IC engines that cycle on and off based on a time-of-day schedule (Figure 6-1). The facility site has experienced many swell events that occur during periods of startup of the IC engines but the majority of these events are recorded by the PCC monitor first and then the DG monitor. These events appear to be occurring on the distribution system and by review of the individual events; it is found that they occur late afternoon. This condition may be cycling of capacitor banks for voltage control on the feeder.

FIGURE 6-1: TYPICAL DAILY LOAD PROFILE FOR SAN DIEGO NGIC



6.3 Project Safety and Reliability

6.3.1 Outages caused by DG sites monitored

No outages were caused by the DG and only one distribution outage (9% pu) occurred at Redlands 11/25/02 @ 13:28:34 for 0.734 sec during the monitoring period from 8/26/02 to 10/31/04.

6.3.2 Safety issues generated by DG sites monitored

No safety issues were generated at any sites that can be contributed to the DG. No islanding events occur during the monitoring project because no feeder outages occur.

6.3.3 Power Quality problems caused by DG

As documented in Section 5, all Power Quality parameters analyzed were well within IEEE Standard requirements and were below the Benchmarks established in the EPRI DQP Project.

6.3.4 Power Quality problems caused by Distribution System

The only known problem that was prorogated through the distribution system and cause problems was the lighting strike in Los Angeles in late October 2003. This event caused and SCR failure in the inverter of the Fuel Cell.

6.3.5 Relationship of sites monitored to Rule 21 Simplified Interconnection Requirements

The sites monitored, the data collected and the duration have been far too small to consider eliminating or modifying any interconnection screens.

6.4 Project Recommendations

6.4.1 Increase Study Size

The sample size for this project was established as 9 sites with 16 DGs and 23 monitors gathering data from four types of DG technologies. The sample-size results provide a very narrow window into DG performance and the interaction with the Distribution System. The statistical significance of the result, although important, will be improved if the sample size and duration of monitoring were increased, and if other similar studies are conducted.

6.4.2 Consider Enhancing the Database Management Software

ION Enterprise Software limitation surfaced as a result of the development of this report. Specifically this limitation is in the area of database management and the report generator. As currently configured, it is not possible to combine Archive databases, which then limits the data analysis requiring manual generation and development of workarounds. The Vista standard and custom reports are of limited value in assessing Power Quality analysis. In future, consideration should be given to PQ View by Electrotek (developed for EPRI) and provides Electric Power Distribution Reliability Indices specified in IEEE Std. 1366-2003. Additional study is required to find alternative software available that can import and manage the Power Measurement ION Database.

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APPENDIX A: MONITORING AVAILABILITY

Appendix A – Monitoring Availability

Availability Report

Reflective Energies

From: July-01-2002, 00:00
To: Dec-01-2002, 00:00

Site	Jan-02	Feb-02	Mar-02	Apr-02	May-02	Jun-02	Jul-02	Aug-02	Sep-02	Oct-02	Nov-02	Dec-02	Total Hrs Meter is Running	%
Available Hours	*744*	*672*	*744*	*720*	*744*	*720*	*744*	*744*	*720*	*744*	*720*	*744*	*8760*	
Irvine														
PCC									544.33	744	720	744	2752.33	99.98
FC									544.33	744	720	744	2752.33	99.98
Los Angeles														
PCC														
FC														
NGMT1														
NGMT2														
NGMT3														
Redlands														
PCC								137.33	720	743.75	720	744	3065.08	99.97
NGMT								137.33	720	743.75	720	744	3065.08	99.97
San Diego														
PCC														
NGIC														
South Gate														
PCC										331.75	713	744	1788.75	99.54
PV										332.5	712.5	744	1789	99.55
Sunnyvale														
PCC														
NGIC														
2002 Availability Average for all Sites														99.83

Appendix A – Availability

Availability Report

Reflective Energies

From: Jan-01-2003, 00:00
To: Dec-31-2003, 00:00

Site	Jan-03	Feb-03	Mar-03	Apr-03	May-03	Jun-03	Jul-03	Aug-03	Sep-03	Oct-03	Nov-03	Dec-03	Total Hrs Meter is Running	%
Available Hours	*744*	*672*	*744*	*720*	*744*	*720*	*744*	*744*	*720*	*744*	*720*	*744*	*8760*	
Irvine														
PCC	744	671.25	743.25	719	744	720	743.75	744	720	745	720	744	8758.25	99.98
FC	744	671	743.5	715.5	743.75	720	743.75	744	719.75	745	720	744	8754.25	99.93
Los Angeles														
PCC				470.5	744	670.75	744	744	720	745	720	744	6302.25	99.23
FC				470.5	743.75	680.75	744	744	720	745	720	744	6312	99.39
NGMT1				470.25	743.5	720	744	744	720	745	720	744	6350.75	100.00
NGMT2				470	743.75	648.25	744	744	720	745	720	744	6279	98.87
NGMT3				470.5	743.75	657	744	744	720	745	720	744	6288.25	99.01
Redlands														
PCC	744	672	743.75	719	744	720	744	744	720	744.5	720	744	8759.25	99.99
NGMT	744	672.25	743.75	719	743.5	720	744	744	720	744.5	720	744	8759	99.99
San Diego														
PCC	261	664.5	743.5	719	744	719.5	744	744	720	745	720	744	8268.5	99.90
NGIC	261	664.75	746	719	743.75	719.5	744	744	719.75	745	720	744	8269.75	99.91
South Gate														
PCC	741.5	672.25	741.25	719.25	744	720	744	744	720	744.75	720	744	8755	99.94
PV	741.75	672	741.25	719	744	720	744	744	718.25	745	720	744	8753.25	99.92
Sunnyvale														
PCC			179.75	719	744	720	744	744	720	745	720	744	6779.75	100.00
NGIC			552.25	718.75	744	720	744	743.25	720	745	720	744	7151.25	99.98
2003 Availability Average for all Sites														99.74

Appendix A – Availability

Availability Report

Reflective Energies

From: Jan-01-2004, 00:00
To: Dec-31-2004, 00:00

Site	Jan-04	Feb-04	Mar-04	Apr-04	May-04	Jun-04	Jul-04	Aug-04	Sep-04	Oct-04	Nov-04	Dec-04	Total Hrs Meter is Running	%
Available Hours	*744*	*696*	*744*	*720*	*744*	*720*	*744*	*744*	*720*	*144*			*6720*	
Irvine														
PCC	744	696	744	719	744	720	744	744	720	744			7319	100.00
FC	744	696	744	719	744	720	744	744	720	744			7319	100.00
Los Angeles														
PCC	744	696	744	719	744	720	744	744	720	744			7319	100.00
FC	744	696	744	719	744	720	744	744	720	744			7319	100.00
NGMT1	744	696	744	719	744	720	744	744	720	744			7319	100.00
NGMT2	744	696	744	719	744	720	744	744	720	744			7319	100.00
NGMT3	744	696	744	719	744	720	744	744	720	744			7319	100.00
Redlands														
PCC	743.75	696	744	719	743.5	720	744	744	718.5	744			7316.75	99.97
NGMT	743.75	696	744	719	744	720	744	744	718.5	744			7317.25	99.98
San Diego														
PCC	744	691	744	719	744	720	744	744	720	744			7314	99.93
NGIC	744	691	744	719	744	720	744	744	720	744			7314	99.93
South Gate										**Note 1**				
PCC	744	695.75	744	719	744	720	744	744	720	744			7318.75	100.00
PV	744	695.75	744	719	744	720	744	744	720	743.25			7318	99.99
Sunnyvale														
PCC	744	696	744	719	744	720	744	744	720	744			7319	100.00
NGIC	744	696	744	719	744	720	744	744	720	744			7319	100.00
2004 Availability Average for all Sites														**99.99**
Overall Availability Average for all Sites														**99.86**

Note 1 - Firmwwre upgrade at South Gate requires shut down of PV monitor and results is loss of some data

APPENDIX B: PQ SUMMARY

Appendix B – PQ Summary

Power Quality Summary

Reflective Energy

From: January 1, 2002
To: January 1, 2003

Site	Jan-02	Feb-02	Mar-02	Apr-02	May-02	Jun-02	Jul-02	Aug-02	Sep-02	Oct-02	Nov-02	Dec-02	Total	Total/Day
Irvine									Note 1					
PCC														
# of Disturbances									26	44	43	56	169	0.08
#Transients									25	44	42	51	162	0.08
# Sags									1	0	1	5	7	0.00
# Swells									0	0	0	0	0	0.00
FC														
# of Disturbances									25	45	43	58	171	0.08
#Transients									24	45	42	53	164	0.08
# Sags									1	0	1	5	7	0.00
# Swells									0	0	0	0	0	0.00
Redlands								Note 2						
PCC														
# of Disturbances								0	82	54	68	29	233	1.82
#Transients								0	79	43	47	27	196	1.53
# Sags								0	3	11	21	2	37	0.29
# Swells								0	0	0	0	0	0	0.00
NGMT														
# of Disturbances								0	82	54	66	30	232	1.82
#Transients								0	79	43	45	28	195	1.53
# Sags								0	3	11	21	2	37	0.29
# Swells								0	0	0	0	0	0	0.00
South Gate										Note 3				
PCC														
# of Disturbances										0	2	6	8	0.11
#Transients										0	1	4	5	0.07
# Sags										0	1	2	3	0.04
# Swells										0	0	0	0	0.00
PV														
# of Disturbances										0	3	7	10	0.13
#Transients										0	2	5	7	0.09
# Sags										0	1	2	3	0.04
# Swells										0	0	0	0	0.00

2002 Notes

1. Irvine Site Activation Note
   Monitors installed 9/8/02, DSL Installed 8/26/02, Data from 9/8/02 @ 07:45
2. Redland Site Activation Note
   Monitors installed 8/26/02, DSL Installed 9/2/02, Data from 8/26/02 @ 06:45
2. South Gate Site Activation Note
   Monitors installed 9/11/02, DSL Installed 10/14/02, Data from 10/18/02 @ 04:45

Power Quality Summary

Reflective Energy

From: January 1, 2003
To: January 1, 2004

Site	Jan-03	Feb-03	Mar-03	Apr-03	May-03	Jun-03	Jul-03	Aug-03	Sep-03	Oct-03	Nov-03	Dec-03	Total	Total/Day
Irvine														
PCC														
# of Disturbances	54	30	52	49	69	49	45	40	133	63	50	71	705	1.93
#Transients	51	29	37	47	67	48	45	40	133	62	49	68	676	1.85
# Sags	3	1	15	2	2	1	0	0	0	1	1	3	29	0.08
# Swells	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
FC														
# of Disturbances	52	30	51	50	69	49	38	39	48	62	65	66	619	1.70
#Transients	49	29	37	48	68	48	38	39	48	61	64	63	592	1.62
# Sags	3	1	14	2	1	1	0	0	0	1	1	3	27	0.07
# Swells	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
Los Angeles						Note 1					Note 2			
PCC														
# of Disturbances						30	212	2	170	228	646	7	1295	6.55
#Transients						28	210	0	170	227	646	7	1288	6.52
# Sags						2	0	2	0	1	0	0	5	0.03
# Swells						0	2	0	0	0	0	0	2	0.01
FC														
# of Disturbances						36	242	2	166	214	1024	4	1688	8.54
#Transients						34	238	0	166	213	1024	4	1679	8.50
# Sags						2	0	2	0	1	0	0	5	0.03
# Swells						0	4	0	0	0	0	0	4	0.02
NGMT1														
# of Disturbances						33	295	2	218	7636	215534	3	223721	1132.41
#Transients						31	292	0	218	7635	215534	3	223713	1132.37
# Sags						2	0	2	0	1	0	0	5	0.03
# Swells						0	3	0	0	0	0	0	3	0.02
NGMT2														
# of Disturbances						32	262	2	167	267	1017	2	1749	8.85
#Transients						30	258	0	167	266	1017	2	1740	8.81
# Sags						2	0	2	0	1	0	0	5	0.03
# Swells						0	4	0	0	0	0	0	4	0.02
NGMT3														
# of Disturbances						33	251	2	118	246	702	7	1359	6.88
#Transients						30	248	0	118	246	702	7	1351	6.84
# Sags						2	0	2	0	0	0	0	4	0.02
# Swells						1	3	0	0	0	0	0	4	0.02
Redlands														
PCC														
# of Disturbances	52	41	33	45	57	66	112	121	81	73	5	2	688	1.88
#Transients	47	28	32	38	55	66	110	119	80	54	4	1	634	1.74
# Sags	5	13	1	7	2	0	2	2	1	19	1	1	54	0.15
# Swells	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
NGMT														
# of Disturbances	51	40	32	46	60	67	110	126	82	76	5	2	697	1.91
#Transients	46	28	31	39	58	67	108	124	81	57	4	1	644	1.76
# Sags	5	12	1	7	2	0	2	2	1	19	1	1	53	0.15
# Swells	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00

Power Quality Summary

Reflective Energy

From: January 1, 2003
To: January 1, 2004

Site	Jan-03	Feb-03	Mar-03	Apr-03	May-03	Jun-03	Jul-03	Aug-03	Sep-03	Oct-03	Nov-03	Dec-03	Total	Total/Day
San Diego	Note 3													
PCC														
# of Disturbances	0	9	20	137	239	189	97	212	518	1071	159	1042	3693	10.71
#Transients	0	8	11	10	28	32	39	41	60	59	39	32	359	1.04
# Sags	0	1	2	0	1	0	0	0	3	15	0	4	26	0.08
# Swells	0	0	7	127	210	157	58	171	455	997	120	1006	3308	9.59
NGIC														
# of Disturbances	0	10	36	120	202	222	109	240	850	1416	218	1163	4586	13.30
#Transients	0	9	23	10	28	30	38	44	58	58	36	31	365	1.06
# Sags	0	1	2	0	1	0	0	0	3	15	0	4	26	0.08
# Swells	0	0	11	110	173	192	71	196	789	1343	182	1128	4195	12.16
South Gate														
PCC														
# of Disturbances	25	0	9	5	8	3	2	7	16	15	12	22	124	0.34
#Transients	20	0	5	2	8	2	2	7	10	4	7	17	84	0.23
# Sags	5	0	4	3	0	1	0	0	6	11	5	5	40	0.11
# Swells	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
PV														
# of Disturbances	24	1	21	4	10	3	5	7	16	14	14	22	141	0.39
#Transients	19	1	5	1	10	2	5	7	10	4	9	17	90	0.25
# Sags	5	0	4	3	0	1	0	0	6	10	5	5	39	0.11
# Swells	0	0	12	0	0	0	0	0	0	0	0	0	12	0.03
Sunnyvale				Note 4										
PCC														
# of Disturbances				0	0	0	29	9	81	48	9	10	186	0.71
#Transients				0	0	0	28	5	77	47	0	4	161	0.62
# Sags				0	0	0	1	4	4	1	9	6	25	0.10
# Swells				0	0	0	0	0	0	0	0	0	0	0.00
NGIC														
# of Disturbances				5	2	0	1	1	1	1	0	1	12	0.05
#Transients				0	0	0	0	0	0	0	0	0	0	0.00
# Sags				5	2	0	1	1	1	1	0	1	12	0.05
# Swells				0	0	0	0	0	0	0	0	0	0	0.00

2003 Notes

1. Los Angeles Site Activation Note
   05/02/03 to 06/23/03 - After two visits to the Los Angeles site, wiring and phasing issues were resolved. Monitoring of the downloaded data found high incidences of sag, swells and transients. The problem appears to be related to a site line-to-neutral voltage unbalance. The high level of THD and, perhaps also the voltage unbalance is probably related to the 480V system neutral grounding rather than the Fuel Cell or Capstone inverters. Monitor wiring was reconfigured from Wye to Delta and resolve the site issues. Data from 06/17/03 @ 10:30
2. Los Angeles Site November Note
   10/31/03 to 11/08/03 - Los Angeles site has a lighting strike which trips the Fuel Cell but NGMT1 continues to operate. NGMT1 starts recording Transients events continuously and by the end of the month a total of 7635 is entered into the database. Because the Transient events were in a constant alarm condition, the database capture feature was turned off 11/03 @ 11pm. The Fuel Cell is returned to service 11/6 after a blown SCR is replaced. The Waveform & Transient capture is reactivated 11/08 @ 10pm.
3. San Diego Site Activation Note
   Monitors installed 1/20/03, DSL Installed 2/10/03, Data from 1/21/03 @ 03:15 am
4. Sunnyvale Site Activation Note
   PCC Monitors installed 11/14/02, NGIC Monitor Installed 1/15/03, DSL & Wireless Ethernet System on-line 4/7/03, Data from 4/15/03 @ 05:30 after re-configuration of monitor Framework

Power Quality Summary

Reflective Energy

From: January 1,2004
To: January 1,2005

Site		Jan-04	Feb-04	Mar-04	Apr-04	May-04	Jun-04	Jul-04	Aug-04	Sep-04	Oct-04	Nov-04	Dec-04	Total	Total/Day
Irvine															
PCC															
	# of Disturbances	59	50	44	34	52	40	46	44	65	71			505	1.38
	#Transients	59	47	43	29	48	38	43	43	65	71			486	1.33
	# Sags	0	3	1	5	4	2	3	1	0	0			19	0.05
	# Swells	0	0	0	0	0	0	0	0	0	0			0	0.00
FC															
	# of Disturbances	58	53	44	37	51	40	49	46	66	69			513	1.41
	#Transients	58	50	43	32	47	38	46	45	66	69			494	1.35
	# Sags	0	3	1	5	4	2	3	1	0	0			19	0.05
	# Swells	0	0	0	0	0	0	0	0	0	0			0	0.00
Los Angeles															
PCC															
	# of Disturbances	28	12	296	14	18	328	33	24	4	0			757	3.72
	#Transients	25	8	294	1	16	328	31	23	2	0			728	3.58
	# Sags	3	4	2	1	2	0	2	1	2	0			17	0.08
	# Swells	0	0	0	12	0	0	0	0	0	0			12	0.06
FC															
	# of Disturbances	22	16	291	10	19	426	32	22	4	0			842	4.14
	#Transients	19	8	289	3	17	426	30	21	2	0			815	4.00
	# Sags	3	4	2	1	2	0	2	1	2	0			17	0.08
	# Swells	0	4	0	6	0	0	0	0	0	0			10	0.05
NGMT1															
	# of Disturbances	28	17	233	12	23	382	32	25	4	0			756	3.71
	#Transients	25	9	231	2	21	382	30	24	2	0			726	3.57
	# Sags	3	4	2	1	2	0	2	1	2	0			17	0.08
	# Swells	0	4	0	9	0	0	0	0	0	0			13	0.06
NGMT2															
	# of Disturbances	29	13	217	4	19	391	32	23	4	0			732	3.59
	#Transients	26	7	215	1	17	391	30	22	2	0			711	3.49
	# Sags	3	4	2	1	2	0	2	1	2	0			17	0.08
	# Swells	0	2	0	2	0	0	0	0	0	0			4	0.02
NGMT3															
	# of Disturbances	24	58	266	7	24	400	33	24	4	0			840	4.13
	#Transients	21	8	264	2	22	400	31	23	2	0			773	3.80
	# Sags	3	4	2	1	2	0	2	1	2	0			17	0.08
	# Swells	0	46	0	4	0	0	0	0	0	0			50	0.25
Redlands															
PCC															
	# of Disturbances	20	34	101	52	78	98	145	135	119	66			848	2.32
	#Transients	20	30	87	50	74	97	142	128	115	65			808	2.21
	# Sags	0	4	14	2	4	1	3	7	4	1			40	0.11
	# Swells	0	0	0	0	0	0	0	0	0	0			0	0.00
NGMT															
	# of Disturbances	22	37	98	52	81	96	139	134	125	66			850	2.33
	#Transients	22	33	84	50	77	95	136	128	121	65			811	2.22
	# Sags	0	4	14	2	4	1	3	6	4	1			39	0.11
	# Swells	0	0	0	0	0	0	0	0	0	0			0	0.00

Power Quality Summary

Reflective Energy

From: January 1, 2004
To: January 1, 2005

Site	Jan-04	Feb-04	Mar-04	Apr-04	May-04	Jun-04	Jul-04	Aug-04	Sep-04	Oct-04	Nov-04	Dec-04	Total	Total/Day
San Diego														
PCC														
# of Disturbances	1040	332	728	1728	125	195	195	535	595	72			5545	16.08
#Transients	43	40	28	41	44	49	49	65	53	55			467	1.35
# Sags	1	1	0	0	0	2	2	2	4	3			15	0.04
# Swells	996	291	700	1687	81	144	144	468	538	14			5063	14.68
NGIC														
# of Disturbances	1034	302	824	2119	224	439	380	1047	598	143			7110	20.62
#Transients	48	42	33	38	41	47	70	67	52	53			491	1.42
# Sags	1	1	0	0	0	2	2	2	4	3			15	0.04
# Swells	985	259	791	2081	183	390	308	978	542	87			6604	19.15
San Francisco										Note 1				
PCC														
# of Disturbances													0	0.00
#Transients													0	0.00
# Sags													0	0.00
# Swells													0	0.00
NGIC														
# of Disturbances													0	0.00
#Transients													0	0.00
# Sags													0	0.00
# Swells													0	0.00
South Gate														
PCC														
# of Disturbances	7	12	19	11	162	7	20	20	8	10			276	0.76
#Transients	4	6	17	2	21	5	2	14	6	1			78	0.21
# Sags	3	6	2	9	141	2	18	6	2	9			198	0.54
# Swells	0	0	0	0	0	0	0	0	0	0			0	0.00
PV														
# of Disturbances	9	13	23	13	187	7	17	20	10	10			309	0.85
#Transients	6	7	21	2	22	5	2	14	6	2			87	0.24
# Sags	3	6	2	11	165	2	15	6	4	8			222	0.61
# Swells	0	0	0	0	0	0	0	0	0	0			0	0.00
Sunnyvale														
PCC														
# of Disturbances	4	7	5	118	4	57	99	3	1	6			304	1.24
#Transients	1	6	3	116	1	51	99	2	0	2			281	1.15
# Sags	3	1	2	2	3	6	0	1	1	4			23	0.09
# Swells	0	0	0	0	0	0	0	0	0	0			0	0.00
NGIC														
# of Disturbances	3	1	2	2	2	6	0	1	0	4			21	0.09
#Transients	0	0	0	0	0	1	0	0	0	0			1	0.00
# Sags	3	1	2	2	2	5	0	1	0	4			20	0.08
# Swells	0	0	0	0	0	0	0	0	0	0			0	0.00

2003 Notes
1. San Francisco Site Activation Note
Site Survey 06/14/04, Monitors Installed ________, DSL Installed ________, Data from ________

APPENDIX C: SARFI SUMMARY

Appendix C – SARFI Summary

C.1 Project SARFI by Month

	Undervoltage					Overvoltage			
Total By Month for All Monitors [1]	$SARFI_{10}$	$SARFI_{50}$	$SARFI_{70}$	$SARFI_{80}$	$SARFI_{90}$	$SARFI_{100}$	$SARFI_{110}$	$SARFI_{120}$	$SARFI_{140}$
August-02	0	0	0	0	0	0	0	0	0
September-02	0	0	0	0	3	0	0	0	0
October-02	0	0	1	3	11	0	0	0	0
November-02	1	2	5	10	14	0	0	0	0
December-02	0	0	0	0	7	0	0	0	0
January-03	0	0	1	5	7	0	0	0	0
February-03	0	0	0	2	6	0	0	0	0
March-03	0	0	1	1	11	3	0	0	0
April-03	0	1	1	4	13	1	0	0	0
May-03	0	0	0	0	5	6	0	0	0
June-03	0	1	2	2	4	4	0	0	0
July-03	0	0	0	0	4	2	0	0	0
August-03	0	0	2	2	8	2	0	0	0
September-03	0	0	0	3	13	8	0	0	0
October-03	0	0	11	25	41	14	0	0	0
November-03	0	0	3	4	12	4	0	0	0
December-03	0	1	3	7	16	14	0	0	0
January-04	0	0	2	4	8	16	0	0	0
February-04	0	1	4	5	13	19	0	0	0
March-04	0	1	1	2	10	12	0	0	0
April-04	0	0	0	1	13	12	0	0	0
May-04	0	0	1	3	70	3	0	0	0
June-04	0	1	2	5	10	5	0	0	0
July-04	0	1	1	3	18	7	0	0	0
August-04	0	1	2	4	12	16	0	0	0
September-04	0	1	1	2	13	8	0	0	0
October-04	0	1	4	7	11	7	0	0	0
SARFIx Totals: (From above)	**1**	**12**	**48**	**104**	**353**	**163**	**0**	**0**	**0**
SARFIx Total (Average/365days/monitor):	**0.0305**	**0.4075**	**1.6678**	**3.5858**	**12.2916**	**6.1973**	**0.0000**	**0.0000**	**0.0000**

[1] See Section 5.7 for description of Temporal Aggradations Analysis.

C.2 PCC SARFI by Month

	Undervoltage					Overvoltage			
Total By Month for PCC Monitors	**$SARFI_{10}$**	**$SARFI_{50}$**	**$SARFI_{70}$**	**$SARFI_{80}$**	**$SARFI_{90}$**	**$SARFI_{100}$**	**$SARFI_{110}$**	**$SARFI_{120}$**	**$SARFI_{140}$**
August-02	0	0	0	0	0	0	0	0	0
September-02	0	0	0	0	2	0	0	0	0
October-02	0	0	0	0	4	0	0	0	0
November-02	1	2	5	8	11	0	0	0	0
December-02	0	0	0	0	2	0	0	0	0
January-03	0	0	0	1	1	0	0	0	0
February-03	0	0	0	0	3	0	0	0	0
March-03	0	0	0	0	6	1	0	0	0
April-03	0	1	1	1	5	1	0	0	0
May-03	0	0	0	0	4	5	0	0	0
June-03	0	1	1	1	2	2	0	0	0
July-03	0	0	0	0	3	1	0	0	0
August-03	0	0	2	2	7	2	0	0	0
September-03	0	0	0	2	9	3	0	0	0
October-03	0	0	9	23	35	11	0	0	0
November-03	0	0	2	3	11	1	0	0	0
December-03	0	0	2	6	14	10	0	0	0
January-04	0	0	0	0	0	7	0	0	0
February-04	0	1	4	4	7	9	0	0	0
March-04	0	0	0	1	1	7	0	0	0
April-04	0	0	0	0	3	3	0	0	0
May-04	0	0	0	2	7	2	0	0	0
June-04	0	0	1	1	4	1	0	0	0
July-04	0	1	1	1	2	4	0	0	0
August-04	0	1	2	3	8	11	0	0	0
September-04	0	0	0	0	4	3	0	0	0
October-04	0	1	3	4	5	3	0	0	0
SARFIx Totals:	**1**	**8**	**33**	**63**	**160**	**87**	**0**	**0**	**0**
SARFIx Total (Average/365days/monitor):	**0.0763**	**0.6722**	**2.8326**	**5.3319**	**13.9318**	**8.1440**	**0.0000**	**0.0000**	**0.0000**

C.3 DG SARFI by Month

	Undervoltage					Overvoltage			
Total By Month for DG Monitors	$SARFI_{10}$	$SARFI_{50}$	$SARFI_{70}$	$SARFI_{80}$	$SARFI_{90}$	$SARFI_{100}$	$SARFI_{110}$	$SARFI_{120}$	$SARFI_{140}$
August-02	0	0	0	0	0	0	0	0	0
September-02	0	0	0	0	1	0	0	0	0
October-02	0	0	1	3	7	0	0	0	0
November-02	0	0	0	2	3	0	0	0	0
December-02	0	0	0	0	5	0	0	0	0
January-03	0	0	1	4	6	0	0	0	0
February-03	0	0	0	2	3	0	0	0	0
March-03	0	0	1	1	5	2	0	0	0
April-03	0	0	0	3	8	0	0	0	0
May-03	0	0	0	0	1	1	0	0	0
June-03	0	0	1	1	2	2	0	0	0
July-03	0	0	0	0	1	1	0	0	0
August-03	0	0	0	0	1	0	0	0	0
September-03	0	0	0	1	4	5	0	0	0
October-03	0	0	2	2	6	3	0	0	0
November-03	0	0	1	1	1	3	0	0	0
December-03	0	1	1	1	2	4	0	0	0
January-04	0	0	2	4	8	9	0	0	0
February-04	0	0	0	1	6	10	0	0	0
March-04	0	1	1	1	9	5	0	0	0
April-04	0	0	0	1	10	9	0	0	0
May-04	0	0	1	1	63	1	0	0	0
June-04	0	1	1	4	6	4	0	0	0
July-04	0	0	0	2	16	3	0	0	0
August-04	0	0	0	1	4	5	0	0	0
September-04	0	1	1	2	9	5	0	0	0
October-04	0	0	1	3	6	4	0	0	0
SARFIx Totals:	**0**	**4**	**15**	**41**	**193**	**76**	**0**	**0**	**0**
SARFIx Total (Average/365days/monitor):	**0.0000**	**0.2309**	**0.8912**	**2.4217**	**11.1982**	**4.8995**	**0.0000**	**0.0000**	**0.0000**

C.4 FC SARFI by Month

	Undervoltage					Overvoltage			
Total By Month for FC Monitors	**$SARFI_{10}$**	**$SARFI_{50}$**	**$SARFI_{70}$**	**$SARFI_{80}$**	**$SARFI_{90}$**	**$SARFI_{100}$**	**$SARFI_{110}$**	**$SARFI_{120}$**	**$SARFI_{140}$**
August-02	0	0	0	0	0	0	0	0	0
September-02	0	0	0	0	1	0	0	0	0
October-02	0	0	0	0	0	0	0	0	0
November-02	0	0	0	0	0	0	0	0	0
December-02	0	0	0	0	1	0	0	0	0
January-03	0	0	1	1	2	0	0	0	0
February-03	0	0	0	0	0	0	0	0	0
March-03	0	0	0	0	3	0	0	0	0
April-03	0	0	0	0	0	0	0	0	0
May-03	0	0	0	0	0	0	0	0	0
June-03	0	0	1	1	1	0	0	0	0
July-03	0	0	0	0	0	0	0	0	0
August-03	0	0	0	0	1	0	0	0	0
September-03	0	0	0	0	0	0	0	0	0
October-03	0	0	0	0	0	0	0	0	0
November-03	0	0	0	0	0	0	0	0	0
December-03	0	0	0	0	0	0	0	0	0
January-04	0	0	0	0	0	0	0	0	0
February-04	0	0	0	0	0	1	0	0	0
March-04	0	1	1	1	2	0	0	0	0
April-04	0	0	0	0	2	1	0	0	0
May-04	0	0	0	0	2	0	0	0	0
June-04	0	0	0	2	2	0	0	0	0
July-04	0	0	0	0	2	0	0	0	0
August-04	0	0	0	0	0	0	0	0	0
September-04	0	0	0	0	0	0	0	0	0
October-04	0	0	0	0	0	0	0	0	0
SARFIx Totals:	**0**	**1**	**3**	**5**	**19**	**2**	**0**	**0**	**0**
SARFIx Total (Average/365days/monitor):	**0.0000**	**0.2326**	**0.6977**	**1.1629**	**4.8107**	**0.7263**	**0.0000**	**0.0000**	**0.0000**

C.4 NGMT SARFI by Month

	Undervoltage					Overvoltage			
Total By Month for NGMT Monitors	$SARFI_{10}$	$SARFI_{50}$	$SARFI_{70}$	$SARFI_{80}$	$SARFI_{90}$	$SARFI_{100}$	$SARFI_{110}$	$SARFI_{120}$	$SARFI_{140}$
August-02	0	0	0	0	0	0	0	0	0
September-02	0	0	0	0	0	0	0	0	0
October-02	0	0	1	3	7	0	0	0	0
November-02	0	0	0	2	2	0	0	0	0
December-02	0	0	0	0	2	0	0	0	0
January-03	0	0	0	2	3	0	0	0	0
February-03	0	0	0	2	2	0	0	0	0
March-03	0	0	1	1	1	0	0	0	0
April-03	0	0	0	0	2	0	0	0	0
May-03	0	0	0	0	0	0	0	0	0
June-03	0	0	0	0	1	0	0	0	0
July-03	0	0	0	0	0	1	0	0	0
August-03	0	0	0	0	0	0	0	0	0
September-03	0	0	0	0	0	0	0	0	0
October-03	0	0	1	1	2	0	0	0	0
November-03	0	0	0	0	0	0	0	0	0
December-03	0	0	0	0	1	0	0	0	0
January-04	0	0	1	2	3	0	0	0	0
February-04	0	0	0	1	3	6	0	0	0
March-04	0	0	0	0	5	0	0	0	0
April-04	0	0	0	1	2	0	0	0	0
May-04	0	0	1	1	3	0	0	0	0
June-04	0	0	0	0	0	0	0	0	0
July-04	0	0	0	1	4	0	0	0	0
August-04	0	0	0	1	1	0	0	0	0
September-04	0	0	0	1	4	0	0	0	0
October-04	0	0	0	1	1	0	0	0	0
SARFIx Totals:	**0**	**0**	**5**	**20**	**49**	**7**	**0**	**0**	**0**
SARFIx Total (Average/365days/monitor):	**0.0000**	**0.0000**	**0.7063**	**2.6237**	**6.5456**	**1.2710**	**0.0000**	**0.0000**	**0.0000**

C.5 NGIC SARFI by Month

	Undervoltage					Overvoltage			
Total By Month for NGIC Monitors	**$SARFI_{10}$**	**$SARFI_{50}$**	**$SARFI_{70}$**	**$SARFI_{80}$**	**$SARFI_{90}$**	**$SARFI_{100}$**	**$SARFI_{110}$**	**$SARFI_{120}$**	**$SARFI_{140}$**
August-02	0	0	0	0	0	0	0	0	0
September-02	0	0	0	0	0	0	0	0	0
October-02	0	0	0	0	0	0	0	0	0
November-02	0	0	0	0	0	0	0	0	0
December-02	0	0	0	0	0	0	0	0	0
January-03	0	0	0	0	0	0	0	0	0
February-03	0	0	0	0	1	0	0	0	0
March-03	0	0	0	0	1	1	0	0	0
April-03	0	0	0	2	4	0	0	0	0
May-03	0	0	0	0	1	1	0	0	0
June-03	0	0	0	0	0	2	0	0	0
July-03	0	0	0	0	1	0	0	0	0
August-03	0	0	0	0	0	0	0	0	0
September-03	0	0	0	0	1	5	0	0	0
October-03	0	0	0	0	0	3	0	0	0
November-03	0	0	0	0	0	3	0	0	0
December-03	0	0	0	0	0	4	0	0	0
January-04	0	0	1	2	3	9	0	0	0
February-04	0	0	0	0	2	3	0	0	0
March-04	0	0	0	0	1	5	0	0	0
April-04	0	0	0	0	0	8	0	0	0
May-04	0	0	0	0	2	1	0	0	0
June-04	0	1	1	2	4	4	0	0	0
July-04	0	0	0	1	2	3	0	0	0
August-04	0	0	0	0	2	5	0	0	0
September-04	0	1	1	1	3	5	0	0	0
October-04	0	0	1	2	3	4	0	0	0
SARFIx Totals:	**0**	**2**	**4**	**10**	**31**	**66**	**0**	**0**	**0**
SARFIx Total (Average/365days/monitor):	**0.0000**	**0.5617**	**1.1651**	**3.0170**	**9.4570**	**18.5346**	**0.0000**	**0.0000**	**0.0000**

C.6 PV SARFI by Month

	Undervoltage					Overvoltage			
Total By Month for PV Monitors	$SARFI_{10}$	$SARFI_{50}$	$SARFI_{70}$	$SARFI_{80}$	$SARFI_{90}$	$SARFI_{100}$	$SARFI_{110}$	$SARFI_{120}$	$SARFI_{140}$
August-02	0	0	0	0	0	0	0	0	0
September-02	0	0	0	0	0	0	0	0	0
October-02	0	0	0	0	0	0	0	0	0
November-02	0	0	0	0	1	0	0	0	0
December-02	0	0	0	0	2	0	0	0	0
January-03	0	0	0	1	1	0	0	0	0
February-03	0	0	0	0	0	0	0	0	0
March-03	0	0	0	0	0	1	0	0	0
April-03	0	0	0	1	2	0	0	0	0
May-03	0	0	0	0	0	0	0	0	0
June-03	0	0	0	0	0	0	0	0	0
July-03	0	0	0	0	0	0	0	0	0
August-03	0	0	0	0	0	0	0	0	0
September-03	0	0	0	1	3	0	0	0	0
October-03	0	0	1	1	4	0	0	0	0
November-03	0	0	1	1	1	0	0	0	0
December-03	0	1	1	1	1	0	0	0	0
January-04	0	0	0	0	2	0	0	0	0
February-04	0	0	0	0	1	0	0	0	0
March-04	0	0	0	0	1	0	0	0	0
April-04	0	0	0	0	6	0	0	0	0
May-04	0	0	0	0	56	0	0	0	0
June-04	0	0	0	0	0	0	0	0	0
July-04	0	0	0	0	8	0	0	0	0
August-04	0	0	0	0	1	0	0	0	0
September-04	0	0	0	0	2	0	0	0	0
October-04	0	0	0	0	2	0	0	0	0
SARFIx Totals:	**0**	**1**	**3**	**6**	**94**	**1**	**0**	**0**	**0**
SARFIx Total (Average/365days/monitor):	**0.0000**	**0.4901**	**1.4702**	**2.9404**	**46.0659**	**0.4901**	**0.0000**	**0.0000**	**0.0000**

C.7 Log of Server Sag RMS Events Summary

Duration	0 to 10	10 to 20	20 to 30	30 to 40	40 to 50	50 to 60	60 to 70	70 to 80	80 to 90	Totals
1 c								1	41	**42**
2 c						1		3	52	**56**
3 c								7	35	**42**
4 c		1				2	8	19	29	**59**
5 c			1			3	6	11	8	**29**
5 to 10 c					3	3	7	7	11	**31**
10 to 20 c			1		1		1	1	23	**27**
20 to 30 c					1	1		4	24	**30**
30 to 60 c	1	1	1	1			2	3	20	**29**
1 to 2 s						1	1		2	**4**
2 to 3 s									3	**3**
3 to 4 s										**0**
4 to 5 s										**0**
5 to 10 s										**0**
10 to 50 s									1	**1**
Totals	**1**	**2**	**3**	**1**	**5**	**11**	**25**	**56**	**249**	**353**

C.8 Log of Server Sag RMS Events 0 to 1cycle

Incident ID	Monitor	Time Stamp	Event Type	Phase	Duration	Magnitude
Incident 9	Redlands.PCC	2003-May-15 01:27:52.200	Sag	V3	0.0070000002	87.00
Incident 1	SanDiego.NGIC	2004-Sep-01 01:42:47.458	Sag	V3	0.0080000004	88.00
Incident 89	Redlands.PCC	2003-Jul-30 07:16:04.230	Sag	V1	0.0080000004	87.00
Incident 1	LOSANGELES.NGMT3	2004-Jan-06 06:18:51.895	Sag	V1	0.0080000004	87.00
Incident 1	SOUTHGATE.PV	2003-Apr-01 11:05:06.274	Sag	V2	0.0080000004	88.00
Incident 5	SUNNYVALE.PCC	2003-Aug-17 16:58:48.214	Sag	V2	0.0080000004	88.00
Incident 10	SOUTHGATE.PV	2003-Oct-25 20:46:09.365	Sag	V2	0.0080000004	88.00
Incident 90	SanDiego.PCC	2003-Oct-26 08:00:26.393	Sag	V2	0.0080000004	88.00
Incident 51	LOSANGELES.NGMT1	2003-Oct-29 07:23:00.084	Sag	V3	0.0080000004	88.00
Incident 7	SUNNYVALE.PCC	2003-Nov-09 07:35:41.566	Sag	V1	0.0080000004	86.00
Incident 7	SOUTHGATE.PV	2004-Apr-27 15:14:51.553	Sag	V1	0.0080000004	73.00
Incident 25	SOUTHGATE.PV	2004-May-06 12:40:26.843	Sag	V1	0.0080000004	82.00
Incident 27	SOUTHGATE.PV	2004-May-06 12:53:39.592	Sag	V1	0.0080000004	84.00
Incident 18	Redlands.NGMT	2004-May-06 13:59:14.071	Sag	V3	0.0080000004	84.00
Incident 11	SOUTHGATE.PV	2004-Jul-20 19:06:39.970	Sag	V3	0.0080000004	*84.00*
Incident 8	SOUTHGATE.PV	2004-Oct-27 12:02:16.977	Sag	V1	0.0089999996	85.00
Incident 56	Redlands.PCC	2003-Aug-19 13:06:12.958	Sag	V2	0.0149999997	86.00
Incident 11	SOUTHGATE.PV	2003-Sep-15 08:43:00.963	Sag	V3	0.0160000008	86.00
Incident 2	SOUTHGATE.PV	2004-Sep-05 13:22:38.468	Sag	V2	0.0160000008	86.00
Incident 2	SOUTHGATE.PCC	2003-Sep-02 07:58:10.010	Sag	V1	0.0160000008	86.00
Incident 3	SUNNYVALE.NGIC	2004-Jan-01 11:03:31.991	Sag	V2	0.0160000008	86.00
Incident 9	SUNNYVALE.PCC	2003-Dec-21 02:47:24.930	Sag	V1	0.0160000008	87.00
Incident 2	SOUTHGATE.PV	2002-Dec-16 11:22:00.710	Sag	V1	0.0160000008	87.00
Incident 3	SOUTHGATE.PV	2002-Dec-16 11:33:48.714	Sag	V1	0.0160000008	87.00
Incident 32	Redlands.PCC	2003-Feb-27 11:06:21.147	Sag	V3	0.0160000008	87.00
Incident 60	Redlands.PCC	2003-Oct-29 08:27:33.116	Sag	V1	0.0160000008	87.00
Incident 14	SOUTHGATE.PCC	2003-Dec-25 19:13:53.605	Sag	V3	0.0160000008	87.00
Incident 15	Redlands.NGMT	2002-Dec-16 12:40:54.481	Sag	V2	0.0160000008	88.00
Incident 30	Redlands.NGMT	2003-Apr-24 12:06:01.160	Sag	V1	0.0160000008	88.00
Incident 6	SUNNYVALE.PCC	2003-Nov-09 07:09:20.604	Sag	V1	0.0160000008	88.00
Incident 1	SUNNYVALE.PCC	2003-Dec-01 16:59:50.034	Sag	V2	0.0160000008	88.00
Incident 2	Redlands.NGMT	2003-Dec-14 14:02:20.763	Sag	V3	0.0160000008	88.00
Incident 6	SUNNYVALE.PCC	2004-Jun-16 15:06:14.735	Sag	V2	0.0160000008	88.00
Incident 52	Redlands.NGMT	2004-Jul-13 14:33:42.497	Sag	V2	0.0160000008	88.00

Incident ID	Monitor	Time Stamp	Event Type	Phase	Duration	Magnitude
Incident 8	SanDiego.NGIC	2003-Feb-25 07:02:01.222	Sag	V2	0.0160000008	88.00
Incident 7	SOUTHGATE.PV	2003-Sep-10 14:26:14.029	Sag	V1	0.0160000008	88.00
Incident 3	SUNNYVALE.PCC	2003-Sep-12 12:42:55.092	Sag	V2	0.0160000008	88.00
Incident 9	SOUTHGATE.PCC	2003-Oct-25 05:59:32.809	Sag	V2	0.0160000008	88.00
Incident 8	SUNNYVALE.PCC	2003-Nov-09 07:50:48.365	Sag	V2	0.0160000008	88.00
Incident 6	SOUTHGATE.PV	2004-Apr-27 14:36:33.252	Sag	V1	0.0160000008	88.00
Incident 47	SOUTHGATE.PV	2004-May-07 11:42:43.311	Sag	V1	0.0160000008	88.00
Incident 75	SOUTHGATE.PV	***2004-May-10 14:01:00.195***	***Sag***	***V1***	***0.0160000008***	***88.00***

C.9 Log of Server Sag RMS Events 1 to 2 cycle

Incident ID	Monitor	Time Stamp	Event Type	Phase	Duration	Magnitude
Incident 2	Redlands.NGMT	2004-Apr-02 06:36:48.543	Sag	V3	0.0170000009	85.00
Incident 1	SUNNYVALE.NGIC	2003-May-28 10:05:10.477	Sag	V2	0.0170000009	87.00
Incident 8	SOUTHGATE.PCC	2003-Sep-10 21:13:06.290	Sag	V2	0.0240000002	82.00
Incident 15	SOUTHGATE.PCC	2003-Oct-29 07:22:56.200	Sag	V1	0.0240000002	85.00
Incident 22	SanDiego.PCC	2003-Mar-29 08:13:38.944	Sag	V3	0.0240000002	86.00
Incident 4	SOUTHGATE.PCC	2003-Oct-15 05:10:22.308	Sag	V2	0.0240000002	86.00
Incident 3	SUNNYVALE.PCC	2003-Nov-09 05:08:34.634	Sag	V2	0.0240000002	86.00
Incident 1	SUNNYVALE.PCC	2004-May-30 13:22:25.525	Sag	V1	0.0240000002	86.00
Incident 4	SUNNYVALE.PCC	2004-May-30 13:22:25.525	Sag	V1	0.0240000002	86.00
Incident 2	SUNNYVALE.NGIC	2004-Jun-09 08:55:49.589	Sag	V1	0.0240000002	86.00
Incident 34	Irvine.PCC	2004-Feb-25 06:29:45.096	Sag	V3	0.0240000002	87.00
Incident 15	SOUTHGATE.PV	2004-May-05 15:25:46.796	Sag	V1	0.0240000002	88.00
Incident 21	SOUTHGATE.PV	2004-May-06 09:26:28.415	Sag	V1	0.0240000002	88.00
Incident 76	SOUTHGATE.PCC	***2004-May-11 13:33:02.243***	***Sag***	***V2***	***0.0240000002***	***88.00***
Incident 23	Irvine.PCC	2002-Dec-16 17:23:03.091	Sag	V3	0.0250000004	82.00
Incident 19	SanDiego.NGIC	2004-Oct-08 02:24:47.269	Sag	V3	0.0250000004	84.00
Incident 3	SOUTHGATE.PV	2002-Nov-30 13:47:57.130	Sag	V1	0.0250000004	85.00
Incident 1	SUNNYVALE.NGIC	2003-Apr-19 08:08:28.016	Sag	V1	0.0250000004	86.00
Incident 49	Redlands.PCC	2003-Oct-25 20:46:11.427	Sag	V1	0.0250000004	86.00
Incident 1	SUNNYVALE.PCC	2003-Nov-09 01:14:03.195	Sag	V3	0.0250000004	86.00
Incident 33	SanDiego.NGIC	2004-Feb-18 16:54:48.954	Sag	V3	0.0250000004	86.00
Incident 16	LOSANGELES.NGMT1	2004-Jul-17 14:00:27.474	Sag	V3	0.0250000004	86.00
Incident 62	SanDiego.NGIC	2004-Jul-20 19:36:21.235	Sag	V2	0.0250000004	86.00
Incident 2	SUNNYVALE.NGIC	2003-Apr-23 20:25:06.764	Sag	V1	0.0250000004	87.00
Incident 2	SUNNYVALE.PCC	2003-Sep-05 20:56:14.808	Sag	V2	0.0250000004	87.00
Incident 2	SUNNYVALE.PCC	2003-Nov-09 04:52:17.020	Sag	V1	0.0250000004	87.00
Incident 5	SUNNYVALE.PCC	2003-Nov-09 06:32:41.738	Sag	V1	0.0250000004	87.00
Incident 2	SUNNYVALE.NGIC	2004-May-20 12:16:18.722	Sag	V3	0.0250000004	87.00
Incident 91	Redlands.PCC	2003-Jul-30 10:37:34.965	Sag	V2	0.0250000004	88.00
Incident 9	SOUTHGATE.PV	2003-Oct-25 18:32:30.721	Sag	V2	0.0250000004	88.00
Incident 54	SOUTHGATE.PV	2004-May-07 12:39:53.208	Sag	V1	0.0250000004	88.00
Incident 81	SOUTHGATE.PCC	***2004-May-22 08:18:05.972***	***Sag***	***V1***	***0.0250000004***	***88.00***
Incident 59	Redlands.PCC	2003-Oct-29 07:23:00.416	Sag	V2	0.0320000015	73.00
Incident 1	SUNNYVALE.NGIC	2004-May-09 16:33:35.149	Sag	V1	0.0320000015	82.00

Incident ID	Monitor	Time Stamp	Event Type	Phase	Duration	Magnitude
Incident 12	*SOUTHGATE.PV*	2003-Oct-27 09:42:43.190	*Sag *Exceeds Tolerance*	*V2*	*0.0329999998*	*55.00*
Incident 45	Redlands.PCC	2003-Oct-25 08:31:23.545	Sag	V3	0.0329999998	73.00
Incident 6	SOUTHGATE.PCC	2003-Oct-15 23:48:28.922	Sag	V1	0.0329999998	79.00
Incident 9	SOUTHGATE.PCC	2003-Sep-11 00:07:43.241	Sag	V2	0.0329999998	80.00
Incident 37	Redlands.PCC	2002-Oct-19 09:11:23.695	Sag	V2	0.0329999998	81.00
Incident 33	Redlands.PCC	2002-Oct-18 00:03:26.006	Sag	V1	0.0329999998	85.00
Incident 38	Irvine.PCC	2003-Oct-25 20:48:02.497	Sag	V1	0.0329999998	85.00
Incident 1	Irvine.PCC	2002-Sep-12 06:15:09.905	Sag	V1	0.0329999998	86.00
Incident 8	Redlands.PCC	2003-May-15 01:21:37.852	Sag	V3	0.0329999998	86.00
Incident 1	LOSANGELES.PCC	2003-Aug-21 23:53:04.803	Sag	V2	0.0329999998	86.00
Incident 3	SOUTHGATE.PCC	2003-Oct-15 04:51:16.788	Sag	V1	0.0329999998	86.00
Incident 1	SOUTHGATE.PV	2004-Jul-13 14:33:43.484	Sag	V1	0.0329999998	86.00
Incident 15	LOSANGELES.NGMT1	2004-Jul-17 12:56:25.431	Sag	V3	0.0329999998	86.00
Incident 3	SOUTHGATE.PCC	2004-Oct-16 21:31:04.056	Sag	V2	0.0329999998	86.00
Incident 1	SUNNYVALE.NGIC	2003-Sep-04 06:20:18.043	Sag	V1	0.0329999998	87.00
Incident 99	SanDiego.PCC	2003-Oct-26 19:28:33.363	Sag	V1	0.0329999998	87.00
Incident 4	SUNNYVALE.PCC	2003-Dec-08 09:51:15.103	Sag	V1	0.0329999998	87.00
Incident 17	LOSANGELES.NGMT3	2004-Feb-06 18:23:09.428	Sag	V1	0.0329999998	87.00
Incident 74	SanDiego.NGIC	2004-Sep-27 00:59:22.751	Sag	V1	0.0329999998	87.00
Incident 20	Irvine.FC	2003-Mar-16 04:50:01.862	Sag	V3	0.0329999998	88.00
Incident 53	SOUTHGATE.PV	2004-May-07 12:25:17.994	Sag	V1	0.0329999998	88.00
Incident 4	SOUTHGATE.PV	2004-Sep-10 14:06:38.350	Sag	V1	0.0329999998	88.00

C.10 Log of Server Sag RMS Events 2 to 3 cycle

Incident ID	Monitor	Time Stamp	Event Type	Phase	Duration	Magnitude
Incident 34	Redlands.PCC	2002-Oct-18 00:34:00.624	Sag	V1	0.0340000018	85.00
Incident 4	SUNNYVALE.PCC	2003-Aug-12 12:59:03.689	Sag	V1	0.0340000018	86.00
Incident 8	SUNNYVALE.PCC	2003-Dec-21 01:32:46.964	Sag	V1	0.0340000018	86.00
Incident 10	Redlands.NGMT	2002-Nov-08 04:44:59.932	Sag	V1	0.0410000011	76.00
Incident 5	SUNNYVALE.PCC	2003-Dec-12 13:45:36.312	Sag	V1	0.0410000011	77.00
Incident 9	Redlands.NGMT	2002-Nov-08 04:37:14.297	Sag	V3	0.0410000011	79.00
Incident 7	LOSANGELES.PCC	2004-May-11 13:33:02.525	Sag	V1	0.0410000011	79.00
Incident 29	Redlands.NGMT	2002-Oct-14 07:57:38.133	Sag	V3	0.0410000011	80.00
Incident 38	Redlands.PCC	2002-Oct-19 13:08:27.414	Sag	V2	0.0410000011	81.00
Incident 42	Irvine.PCC	2003-Apr-29 09:21:03.998	Sag	V1	0.0410000011	82.00
Incident 61	SanDiego.PCC	2003-Dec-22 17:46:16.921	Sag	V2	0.0410000011	82.00
Incident 1	Irvine.PCC	2003-Feb-03 06:55:09.913	Sag	V2	0.0410000011	83.00
Incident 7	SOUTHGATE.PCC	2003-Mar-21 18:43:44.945	Sag	V1	0.0410000011	83.00
Incident 5	LOSANGELES.NGMT3	2004-Mar-09 03:54:55.478	Sag	V1	0.0410000011	83.00
Incident 2	SOUTHGATE.PCC	2003-Jun-17 06:12:11.279	Sag	V2	0.0410000011	84.00
Incident 3	SUNNYVALE.PCC	2003-Jul-27 05:57:27.554	Sag	V3	0.0410000011	84.00
Incident 1	SUNNYVALE.PCC	2004-Jun-05 12:05:01.291	Sag	V1	0.0410000011	84.00
Incident 1	Irvine.FC	2002-Sep-11 23:09:56.318	Sag	V1	0.0410000011	86.00
Incident 19	LOSANGELES.NGMT2	2003-Jun-30 05:23:37.528	Sag	V3	0.0410000011	86.00
Incident 12	SOUTHGATE.PV	2003-Sep-16 07:35:25.905	Sag	V1	0.0410000011	86.00
Incident 4	SOUTHGATE.PV	2004-Feb-27 09:58:20.050	Sag	V2	0.0410000011	86.00
Incident 5	SOUTHGATE.PV	2004-May-04 17:55:48.991	Sag	V1	0.0410000011	86.00
Incident 29	Irvine.FC	2004-Jul-25 18:37:25.755	Sag	V2	0.0410000011	86.00
Incident 103	Redlands.NGMT	2004-Sep-28 06:17:53.280	Sag	V1	0.0410000011	86.00
Incident 95	SanDiego.PCC	2003-Oct-26 14:22:18.819	Sag	V3	0.0410000011	87.00
Incident 61	Redlands.NGMT	2004-Mar-23 07:09:16.594	Sag	V2	0.0410000011	87.00
Incident 29	Redlands.PCC	***2004-Sep-07 15:32:04.235***	***Sag***	***V2***	***0.0410000011***	***87.00***
Incident 74	SOUTHGATE.PV	2004-May-10 13:56:17.264	Sag	V1	0.0410000011	88.00
Incident 17	Redlands.PCC	2003-Oct-15 05:10:22.758	Sag	V1	0.0419999994	77.00
Incident 28	Redlands.NGMT	2002-Oct-14 07:32:49.508	Sag	V2	0.0419999994	83.00
Incident 8	SUNNYVALE.PCC	2003-Aug-24 16:38:04.947	Sag	V3	0.0419999994	84.00
Incident 1	SUNNYVALE.NGIC	2004-Aug-25 10:12:27.360	Sag	V2	0.0419999994	84.00
Incident 34	Redlands.PCC	2003-Apr-29 09:21:03.761	Sag	V1	0.0419999994	86.00
Incident 1	SUNNYVALE.NGIC	2004-Jun-06 18:40:58.773	Sag	V3	0.0419999994	86.00

Incident ID	Monitor	Time Stamp	Event Type	Phase	Duration	Magnitude
Incident 37	SanDiego.PCC	2004-Sep-19 13:57:43.121	Sag	V2	0.0419999994	86.00
Incident 39	Redlands.PCC	2003-Oct-24 13:06:29.389	Sag	V3	0.0480000004	78.00
Incident 42	Redlands.PCC	2004-Aug-13 09:34:50.747	Sag	V1	0.0489999987	77.00
Incident 1	SUNNYVALE.NGIC	2003-Jul-07 18:38:42.991	Sag	V1	0.0489999987	81.00
Incident 35	Irvine.FC	2004-May-28 11:21:31.215	Sag	V1	0.0489999987	83.00
Incident 8	SUNNYVALE.PCC	2004-Apr-13 06:56:16.318	Sag	V1	0.0489999987	84.00
Incident 31	Irvine.PCC	2002-Dec-21 15:30:09.374	Sag	V3	0.0489999987	86.00
Incident 4	SUNNYVALE.PCC	2003-Nov-09 06:06:09.339	Sag	V1	0.0489999987	86.00

C.11 Log of Server Sag RMS Events 3 to 4 cycle

Incident ID	Monitor	Time Stamp	Event Type	Phase	Duration	Magnitude
Incident 50	*Redlands.PCC*	2003-Oct-25 20:48:17.826	*Sag *Exceeds Tolerance*	*V1*	*0.0500000007*	*62.00*
Incident 16	Redlands.PCC	2003-Oct-15 04:51:17.247	Sag	V2	0.0500000007	71.00
Incident 46	Redlands.PCC	2003-Oct-25 09:21:12.101	Sag	V3	0.0500000007	73.00
Incident 48	Redlands.PCC	2003-Oct-25 18:32:32.789	Sag	V1	0.0500000007	74.00
Incident 21	LOSANGELES.NGMT1	2004-Aug-27 16:20:11.590	Sag	V1	0.0500000007	75.00
Incident 3	SUNNYVALE.NGIC	2004-Jun-17 00:48:42.947	Sag	V3	0.0500000007	76.00
Incident 25	Redlands.NGMT	2002-Oct-14 07:09:15.669	Sag	V2	0.0500000007	77.00
Incident 13	Redlands.PCC	2004-May-04 17:55:49.328	Sag	V2	0.0500000007	79.00
Incident 26	Redlands.NGMT	2002-Oct-14 07:20:02.135	Sag	V2	0.0500000007	80.00
Incident 11	SOUTHGATE.PV	2003-Oct-25 20:48:15.750	Sag	V2	0.0500000007	80.00
Incident 7	Irvine.PCC	2003-Dec-03 07:12:19.101	Sag	V3	0.0500000007	80.00
Incident 2	LOSANGELES.FC	2004-Apr-17 16:15:55.045	Sag	V1	0.0500000007	80.00
Incident 32	Irvine.FC	2004-May-28 11:08:17.459	Sag	V1	0.0500000007	81.00
Incident 2	SanDiego.PCC	2003-Mar-02 05:52:38.929	Sag	V2	0.0500000007	83.00
Incident 2	SanDiego.NGIC	2003-Mar-02 05:53:57.657	Sag	V2	0.0500000007	83.00
Incident 4	Irvine.PCC	2004-Aug-04 12:46:41.835	Sag	V1	0.0500000007	85.00
Incident 1	SUNNYVALE.NGIC	2004-Feb-25 22:09:14.091	Sag	V1	0.0500000007	86.00
Incident 15	SOUTHGATE.PV	2004-Aug-21 15:34:24.872	Sag	V1	0.0509999990	84.00
Incident 5	SOUTHGATE.PCC	2004-Sep-28 06:01:04.057	Sag	V1	0.0509999990	86.00
Incident 23	*Redlands.PCC*	2002-Nov-15 01:04:12.112	*Sag *Exceeds Tolerance*	*V1*	*0.0579999983*	*50.00*
Incident 30	Redlands.NGMT	2002-Oct-14 08:06:54.290	Sag	V3	0.0579999983	68.00
Incident 43	Redlands.PCC	2003-Oct-25 08:19:53.098	Sag	V1	0.0579999983	70.00
Incident 36	Redlands.PCC	2003-Sep-16 07:35:26.180	Sag	V2	0.0579999983	74.00
Incident 13	SanDiego.NGIC	2004-Oct-06 00:51:13.406	Sag	V2	0.0579999983	77.00
Incident 102	Redlands.NGMT	2004-Sep-28 06:01:03.612	Sag	V2	0.0579999983	78.00
Incident 27	Redlands.NGMT	2004-Oct-12 15:51:21.218	Sag	V1	0.0579999983	78.00
Incident 5	SOUTHGATE.PCC	2003-Apr-29 09:21:03.863	Sag	V1	0.0579999983	80.00
Incident 27	Redlands.NGMT	2002-Oct-14 07:29:17.456	Sag	V3	0.0579999983	81.00
Incident 108	LOSANGELES.FC	2004-Mar-16 06:09:42.768	Sag	V3	0.0579999983	84.00
Incident 2	SOUTHGATE.PV	2004-Oct-12 15:51:21.664	Sag	V2	0.0579999983	84.00
Incident 2	SUNNYVALE.NGIC	2004-Mar-17 09:13:28.861	Sag	V1	0.0579999983	85.00
Incident 8	SOUTHGATE.PCC	2003-Mar-21 18:53:40.269	Sag	V1	0.0579999983	86.00
Incident 100	SanDiego.PCC	2003-Oct-26 21:10:25.978	Sag	V2	0.0590000004	85.00
Incident 101	SanDiego.PCC	2003-Oct-26 21:46:40.951	Sag	V1	0.0590000004	86.00

Incident ID	Monitor	Time Stamp	Event Type	Phase	Duration	Magnitude
Incident 7	SOUTHGATE.PV	2004-May-05 12:39:22.163	Sag	V1	0.0590000004	88.00
Incident 57	***Redlands.PCC***	2003-Aug-19 13:22:21.981	***Sag *Exceeds Tolerance***	***V3***	***0.0649999976***	***60.00***
Incident 40	Redlands.PCC	2003-Oct-24 13:10:53.559	Sag	V1	0.0649999976	68.00
Incident 42	*SanDiego.NGIC*	2004-Jun-14 22:10:05.602	*Sag *Exceeds Tolerance*	*V2*	*0.0659999996*	*15.00*
Incident 59	*SanDiego.NGIC*	2004-Jan-17 06:29:12.321	*Sag *Exceeds Tolerance*	*V1*	*0.0659999996*	*51.00*
Incident 35	Redlands.NGMT	2003-Oct-24 10:11:32.366	Sag	V1	0.0659999996	64.00
Incident 10	Irvine.FC	2003-Jan-06 00:51:05.275	Sag	V1	0.0659999996	65.00
Incident 1	LOSANGELES.NGMT1	2004-May-03 00:22:12.020	Sag	V2	0.0659999996	66.00
Incident 38	Redlands.PCC	2003-Oct-24 11:33:44.301	Sag	V1	0.0659999996	68.00
Incident 24	Redlands.NGMT	2002-Oct-14 06:31:54.877	Sag	V3	0.0659999996	70.00
Incident 3	SUNNYVALE.NGIC	2003-Apr-23 21:08:46.816	Sag	V1	0.0659999996	71.00
Incident 90	SanDiego.NGIC	2004-Jul-30 09:48:41.061	Sag	V1	0.0659999996	73.00
Incident 87	SanDiego.PCC	2003-Oct-26 07:28:51.537	Sag	V1	0.0659999996	76.00
Incident 51	Redlands.PCC	2003-Oct-26 04:55:53.302	Sag	V1	0.0659999996	77.00
Incident 47	Irvine.PCC	2003-Dec-25 18:06:40.775	Sag	V2	0.0659999996	77.00
Incident 5	SOUTHGATE.PCC	2003-Oct-15 21:31:58.898	Sag	V1	0.0659999996	78.00
Incident 43	Redlands.PCC	2002-Nov-25 09:37:52.764	Sag	V1	0.0659999996	80.00
Incident 14	Irvine.FC	2004-Jul-11 04:31:38.418	Sag	V1	0.0659999996	80.00
Incident 7	SUNNYVALE.PCC	2003-Dec-19 16:32:45.413	Sag	V2	0.0659999996	82.00
Incident 2	LOSANGELES.NGMT2	2004-Sep-13 15:22:25.826	Sag	V1	0.0659999996	84.00
Incident 31	SanDiego.PCC	2003-May-24 14:09:46.331	Sag	V3	0.0659999996	86.00
Incident 6	SOUTHGATE.PCC	2004-Apr-29 19:02:43.681	Sag	V1	0.0659999996	86.00
Incident 1	SUNNYVALE.PCC	2004-Sep-03 16:48:44.944	Sag	V3	0.0659999996	86.00
Incident 28	SOUTHGATE.PV	2004-May-06 13:06:08.043	Sag	V1	0.0659999996	88.00
Incident 75	SOUTHGATE.PCC	***2004-May-11 12:48:26.776***	***Sag***	***V1***	***0.0659999996***	***88.00***

C.12 Log of Server Sag RMS Events 4 to 5 cycle

Incident ID	Monitor	Time Stamp	Event Type	Phase	Duration	Magnitude
Incident 1	*SUNNYVALE.PCC*	2004-Oct-01 11:42:19.865	*Sag *Exceeds Tolerance*	*V3*	*0.0670000017*	*54.00*
Incident 44	Redlands.PCC	2003-Oct-25 08:29:50.803	Sag	V1	0.0670000017	67.00
Incident 9	SOUTHGATE.PV	2004-Jul-20 15:57:26.095	Sag	V1	0.0670000017	82.00
Incident 5	SOUTHGATE.PCC	2004-Aug-04 12:46:41.785	Sag	V2	0.0670000017	83.00
Incident 4	SUNNYVALE.NGIC	2003-Apr-23 21:09:11.973	Sag	V1	0.0740000010	72.00
Incident 1	SUNNYVALE.PCC	2004-Mar-06 16:55:10.174	Sag	V3	0.0740000010	73.00
Incident 33	Irvine.FC	2003-Jan-22 15:33:17.936	Sag	V3	0.0740000010	81.00
Incident 93	*SanDiego.PCC*	2003-Oct-26 11:25:00.622	*Sag *Exceeds Tolerance*	*V1*	*0.0750000030*	*51.00*
Incident 2	***SUNNYVALE.PCC***	2004-Oct-01 11:53:12.259	***Sag *Exceeds Tolerance***	***V3***	***0.0750000030***	***54.00***
Incident 90	*SanDiego.PCC*	2003-Dec-25 18:06:40.885	*Sag *Exceeds Tolerance*	*V2*	*0.0750000030*	*60.00*
Incident 3	SUNNYVALE.PCC	2003-Aug-09 05:24:53.903	Sag	V1	0.0750000030	65.00
Incident 5	LOSANGELES.PCC	2004-Feb-18 14:17:45.283	Sag	V3	0.0750000030	68.00
Incident 41	Redlands.PCC	2003-Oct-25 05:59:33.988	Sag	V1	0.0750000030	71.00
Incident 3	Redlands.NGMT	2004-Apr-02 06:44:19.187	Sag	V1	0.0750000030	72.00
Incident 23	Irvine.FC	2004-Jun-20 05:31:43.508	Sag	V1	0.0750000030	74.00
Incident 3	Irvine.PCC	2002-Nov-02 18:50:16.579	Sag	V2	0.0750000030	82.00
Incident 4	SanDiego.PCC	2003-Sep-02 16:34:07.685	Sag	V2	0.0750000030	85.00
Incident 3	SUNNYVALE.NGIC	2004-Oct-26 03:33:04.702	Sag	V1	0.0829999968	61.00
Incident 2	LOSANGELES.NGMT2	2004-Jan-06 11:50:19.439	Sag	V1	0.0829999968	67.00
Incident 3	Redlands.PCC	2003-Nov-22 18:46:27.712	Sag	V1	0.0829999968	73.00
Incident 4	LOSANGELES.NGMT2	2004-Jan-13 13:13:03.759	Sag	V1	0.0829999968	73.00
Incident 1	SUNNYVALE.NGIC	2004-Jan-01 09:42:20.962	Sag	V3	0.0829999968	74.00
Incident 14	Redlands.PCC	2002-Nov-08 21:27:31.359	Sag	V3	0.0829999968	75.00
Incident 4	Irvine.FC	2004-Jun-03 09:39:38.584	Sag	V3	0.0829999968	75.00
Incident 13	Redlands.PCC	2002-Nov-08 19:14:46.803	Sag	V3	0.0829999968	76.00
Incident 7	SOUTHGATE.PV	2004-Jan-18 11:47:12.633	Sag	V1	0.0829999968	80.00
Incident 3	SanDiego.PCC	2003-Sep-02 16:18:47.619	Sag	V3	0.0829999968	82.00
Incident 1	LOSANGELES.NGMT2	2004-Sep-13 15:18:01.214	Sag	V1	0.0829999968	84.00
Incident 25	*Redlands.PCC*	2004-Feb-20 15:28:14.945	*Sag*	*V1*	0.0829999968	*24.00*

C.13 Log of Server Sag RMS Events 5 to 10 cycle

Incident ID	Monitor	Time Stamp	Event Type	Phase	Duration	Magnitude
Incident 23	*Redlands.PCC*	2004-Feb-19 08:45:57.979	*Sag *Exceeds Tolerance*	*V3*	*0.0839999989*	*59.00*
Incident 48	Redlands.PCC	2002-Nov-26 12:32:50.883	Sag	V3	0.0900000036	65.00
Incident 35	*Redlands.PCC*	2004-Jul-10 20:48:29.695	*Sag *Exceeds Tolerance*	*V1*	*0.0909999982*	*48.00*
Incident 17	***Irvine.PCC***	2003-Nov-10 06:28:10.004	***Sag *Exceeds Tolerance***	***V2***	***0.0909999982***	***55.00***
Incident 7	Redlands.NGMT	2003-Jan-05 21:32:15.604	Sag	V1	0.0909999982	71.00
Incident 12	Irvine.FC	2003-Mar-12 01:48:35.197	Sag	V1	0.0909999982	82.00
Incident 24	Redlands.NGMT	2004-May-08 08:27:46.944	Sag	V2	0.0909999982	87.00
Incident 29	SOUTHGATE.PV	2004-May-06 13:11:52.429	Sag	V1	0.0909999982	88.00
Incident 73	*SanDiego.NGIC*	2004-Sep-26 23:39:02.599	*Sag *Exceeds Tolerance*	*V1*	*0.0920000002*	*44.00*
Incident 4	SOUTHGATE.PCC	2003-Mar-16 20:33:10.361	Sag	V2	0.0920000002	86.00
Incident 45	Redlands.PCC	2004-Aug-13 11:10:53.807	Sag	V2	0.0989999995	63.00
Incident 97	SanDiego.PCC	2003-Oct-26 14:49:56.357	Sag	V1	0.0989999995	69.00
Incident 14	SOUTHGATE.PCC	2003-Oct-28 12:01:25.626	Sag	V1	0.0989999995	69.00
Incident 3	*SUNNYVALE.PCC*	2003-Oct-22 19:08:13.888	Sag *Exceeds Tolerance	V2	0.1000000015	50.00
Incident 49	Redlands.PCC	2002-Nov-26 12:39:26.566	Sag	V3	0.1000000015	65.00
Incident 13	Irvine.FC	2003-Jun-09 14:53:47.464	Sag	V1	0.1000000015	69.00
Incident 92	SanDiego.PCC	2003-Oct-26 08:01:45.286	Sag	V2	0.1000000015	74.00
Incident 23	SanDiego.PCC	2003-Sep-12 10:01:21.457	Sag	V2	0.1000000015	75.00
Incident 12	Redlands.PCC	2002-Nov-08 17:49:44.076	Sag	V3	0.1000000015	76.00
Incident 2	LOSANGELES.FC	2003-Aug-30 16:19:31.075	Sag	V1	0.1000000015	82.00
Incident 92	SanDiego.PCC	2003-Dec-25 20:03:46.008	Sag	V3	0.1080000028	71.00
Incident 24	SOUTHGATE.PV	2004-May-06 12:01:31.437	Sag	V1	0.1080000028	88.00
Incident 60	*SanDiego.PCC*	2004-Oct-31 08:58:23.934	*Sag *Exceeds Tolerance*	*V2*	*0.1159999967*	*49.00*
Incident 94	SanDiego.PCC	2003-Oct-26 13:57:40.065	Sag	V1	0.1159999967	68.00
Incident 91	SanDiego.PCC	2003-Dec-25 19:53:33.456	Sag	V2	0.1159999967	72.00
Incident 2	SOUTHGATE.PV	2003-Jan-08 01:08:29.727	Sag	V2	0.1159999967	78.00
Incident 3	SanDiego.NGIC	2004-Aug-03 08:53:34.665	Sag	V3	0.1330000013	82.00
Incident 18	Irvine.PCC	2004-Feb-11 11:05:58.314	Sag	V1	0.1340000033	83.00
Incident 38	SOUTHGATE.PV	2004-May-06 15:06:51.448	Sag	V1	0.1410000026	88.00
Incident 6	SOUTHGATE.PV	2004-May-05 11:15:27.908	Sag	V1	0.1500000060	88.00
Incident 42	SOUTHGATE.PV	2004-May-06 15:41:25.376	Sag	V1	0.1580000073	88.00

C.14 Log of Server Sag RMS Events 10 to 20 cycle

Incident ID	Monitor	Time Stamp	Event Type	Phase	Duration	Magnitude
Incident 8	SOUTHGATE.PCC	2004-Feb-29 19:52:09.892	Sag	V2	0.1739999950	85.00
Incident 10	Irvine.PCC	2003-Apr-07 00:25:48.610	Sag	V1	0.1749999970	85.00
Incident 16	SOUTHGATE.PV	2004-May-05 15:33:11.873	Sag	V1	0.1749999970	88.00
Incident 53	Redlands.PCC	2002-Nov-29 23:26:18.480	Sag	V2	0.1829999983	87.00
Incident 4	SOUTHGATE.PV	2004-Apr-27 13:56:57.341	Sag	V1	0.1829999983	88.00
Incident 36	SOUTHGATE.PV	2004-May-06 14:41:39.056	Sag	V1	0.1840000004	88.00
Incident 72	SOUTHGATE.PV	2004-May-10 12:33:53.371	Sag	V1	0.1840000004	88.00
Incident 34	Redlands.NGMT	***2003-Apr-29 17:27:32.405***	***Sag***	***V2***	***0.1909999996***	***84.00***
Incident 73	SOUTHGATE.PV	2004-May-10 13:16:51.139	Sag	V1	0.2000000030	88.00
Incident 9	SOUTHGATE.PV	2004-Mar-08 00:02:12.038	Sag	V2	0.2080000043	86.00
Incident 2	SOUTHGATE.PV	2004-Apr-27 12:18:25.586	Sag	V1	0.2160000056	88.00
Incident 19	SOUTHGATE.PV	2004-May-06 05:37:33.582	Sag	V2	0.2249999940	88.00
Incident 12	SOUTHGATE.PV	2004-Jul-20 19:57:56.119	Sag	V1	0.2339999974	88.00
Incident 18	SOUTHGATE.PV	2004-May-05 16:18:27.548	Sag	V1	0.2409999967	88.00
Incident 26	SOUTHGATE.PV	2004-May-06 12:47:05.408	Sag	V1	0.2409999967	88.00
Incident 44	SOUTHGATE.PV	2004-May-07 11:09:49.685	Sag	V1	0.2409999967	88.00
Incident 66	SOUTHGATE.PV	***2004-May-07 20:13:28.779***	***Sag***	***V1***	***0.2419999987***	***88.00***
Incident 21	***LOSANGELES.PCC***	2003-Jun-30 01:01:29.264	***Sag *Exceeds Tolerance***	***V3***	***0.2489999980***	***21.00***
Incident 19	Irvine.FC	2003-Mar-16 02:59:00.145	Sag	V3	0.2489999980	85.00
Incident 52	SOUTHGATE.PV	2004-May-07 12:13:18.958	Sag	V1	0.2489999980	88.00
Incident 2	SOUTHGATE.PV	2003-Apr-07 00:25:50.745	Sag	V2	0.2579999864	79.00
Incident 20	Irvine.FC	2002-Dec-14 22:08:51.474	Sag	V3	0.2660000026	81.00
Incident 31	Redlands.PCC	2003-Feb-27 10:54:44.986	Sag	V1	0.2759999931	87.00
Incident 8	Redlands.PCC	2003-Apr-07 00:25:50.555	Sag	V2	0.2829999924	44.00
Incident 63	SOUTHGATE.PV	2004-May-07 14:31:50.849	Sag	V1	0.2829999924	88.00
Incident 17	SOUTHGATE.PV	2004-May-05 16:01:53.172	Sag	V1	0.3009999990	88.00
Incident 32	Irvine.PCC	2003-Dec-16 13:42:20.191	Sag	V1	0.3079999983	66.00

C.15 Log of Server Sag RMS Events 20 to 30 cycle

Incident ID	Monitor	Time Stamp	Event Type	Phase	Duration	Magnitude
Incident 13	SOUTHGATE.PV	2004-May-05 13:39:24.008	Sag	V1	0.3339999914	88.00
Incident 45	SOUTHGATE.PV	2004-May-07 11:23:51.153	Sag	V1	0.3339999914	88.00
Incident 8	Redlands.NGMT	2003-Feb-07 12:44:23.203	Sag	V2	0.3499999940	71.00
Incident 46	SOUTHGATE.PV	2004-May-07 11:36:30.904	Sag	V1	0.3510000110	88.00
Incident 65	SOUTHGATE.PV	***2004-May-07 19:52:17.388***	***Sag***	***V2***	***0.3659999967***	***88.00***
Incident 13	Irvine.PCC	2003-May-08 14:05:36.756	Sag	V1	0.3750000000	83.00
Incident 24	Irvine.PCC	2004-Feb-18 13:49:36.446	Sag	V3	0.3840000033	50.00
Incident 60	Redlands.NGMT	2004-Mar-23 06:04:41.058	Sag	V2	0.3910000026	86.00
Incident 16	Redlands.NGMT	2002-Dec-16 17:45:19.521	Sag	V1	0.3989999890	81.00
Incident 95	Redlands.NGMT	2004-Jul-24 23:49:03.414	Sag	V1	0.4000000060	76.00
Incident 3	Irvine.FC	2004-Apr-01 21:14:12.953	Sag	V3	0.4000000060	84.00
Incident 30	SOUTHGATE.PV	2004-May-06 13:19:14.342	Sag	V1	0.4079999924	88.00
Incident 13	Redlands.NGMT	2003-Feb-11 04:00:45.951	Sag	V1	0.4160000086	79.00
Incident 58	Redlands.NGMT	2004-Mar-23 04:37:45.993	Sag	V2	0.4169999957	87.00
Incident 16	Irvine.FC	2004-Mar-15 17:13:26.947	Sag	V1	0.4329999983	49.00
Incident 4	SOUTHGATE.PCC	2004-Aug-02 22:16:59.377	Sag	V2	0.4329999983	85.00
Incident 1	SOUTHGATE.PCC	2004-Aug-02 21:37:52.958	Sag	V2	0.4339999855	84.00
Incident 57	SOUTHGATE.PV	2004-May-07 13:33:39.854	Sag	V1	0.4339999855	88.00
Incident 62	Redlands.NGMT	2004-Mar-23 07:37:48.294	Sag	V2	0.4410000145	86.00
Incident 14	SOUTHGATE.PV	2004-May-05 14:05:07.306	Sag	V1	0.4410000145	88.00
Incident 55	SOUTHGATE.PV	2004-May-07 13:13:02.084	Sag	V1	0.4420000017	88.00
Incident 6	SOUTHGATE.PCC	2004-Oct-17 01:43:31.078	Sag	V1	0.4499999881	77.00
Incident 3	SOUTHGATE.PCC	2004-Aug-02 22:06:45.529	Sag	V2	0.4499999881	84.00
Incident 64	SOUTHGATE.PV	2004-May-07 14:39:32.299	Sag	V1	0.4499999881	88.00
Incident 34	Redlands.NGMT	2004-Feb-27 10:57:55.565	Sag	V1	0.4589999914	81.00
Incident 3	SOUTHGATE.PV	2004-Apr-27 13:22:31.762	Sag	V1	0.4589999914	88.00
Incident 9	SOUTHGATE.PV	2004-May-05 13:19:53.736	Sag	V1	0.4659999907	88.00
Incident 35	SOUTHGATE.PV	2004-May-06 13:57:04.290	Sag	V1	0.4659999907	88.00
Incident 23	SOUTHGATE.PV	2004-May-06 11:55:22.402	Sag	V1	0.4830000103	88.00
Incident 62	SOUTHGATE.PV	2004-May-07 14:23:10.735	Sag	V1	0.4920000136	88.00

C.16 Log of Server Sag RMS Events 30 to 60 cycle

Incident ID	Monitor	Time Stamp	Event Type	Phase	Duration	Magnitude
Incident 13	SOUTHGATE.PV	2004-Jul-21 14:57:29.168	Sag	V3	0.5000000000	85.00
Incident 22	SOUTHGATE.PV	2004-May-06 11:42:04.658	Sag	V1	0.5000000000	88.00
Incident 8	SOUTHGATE.PV	2004-May-05 13:13:42.711	Sag	V1	0.5090000033	88.00
Incident 59	SOUTHGATE.PV	***2004-May-07 14:01:23.562***	***Sag***	***V1***	***0.5249999762***	***88.00***
Incident 2	*LOSANGELES.NGMT3*	2004-Feb-02 18:43:29.093	Sag *Exceeds Tolerance	V1	0.5260000229	77.00
Incident 3	SOUTHGATE.PCC	2003-Mar-15 21:05:21.012	Sag	V2	0.5260000229	86.00
Incident 10	SOUTHGATE.PV	2004-Jul-20 16:41:41.771	Sag	V1	0.5339999795	83.00
Incident 15	SOUTHGATE.PV	2004-Jul-21 15:02:32.529	Sag	V1	0.5410000086	84.00
Incident 49	SOUTHGATE.PV	2004-May-07 11:56:08.277	Sag	V1	0.5410000086	88.00
Incident 5	SOUTHGATE.PV	2004-Apr-27 14:23:51.526	Sag	V1	0.5419999957	88.00
Incident 3	***Redlands.PCC***	2004-Jun-01 13:16:34.328	***Sag *Exceeds Tolerance***	***V1***	***0.5519999862***	***66.00***
Incident 12	*Redlands.PCC*	2003-Jan-06 10:10:55.069	*Sag *Exceeds Tolerance*	*V3*	*0.5920000076*	*72.00*
Incident 43	*Redlands.PCC*	2004-Aug-13 11:09:41.135	Sag *Exceeds Tolerance	V2	0.6420000196	39
Incident 58	SOUTHGATE.PV	2004-May-07 13:40:39.468	Sag	V1	0.6740000248	88.00
Incident 51	SOUTHGATE.PV	2004-May-07 12:07:51.642	Sag	V1	0.6999999881	88.00
Incident 60	SOUTHGATE.PV	2004-May-07 14:08:04.478	Sag	V1	0.7329999804	86.00
Incident 46	*Redlands.PCC*	2002-Nov-25 13:28:34.242	Sag *Exceeds Tolerance	V1	0.7340000272	9.00
Incident 8	Redlands.NGMT	2003-Jan-06 02:20:58.426	Sag	V3	0.7590000033	81.00
Incident 9	***Redlands.NGMT***	2003-Jan-06 03:27:50.333	***Sag *Exceeds Tolerance***	***V3***	***0.7919999957***	***76.00***
Incident 48	SOUTHGATE.PV	2004-May-07 11:49:10.260	Sag	V1	0.8000000119	88.00
Incident 16	***SOUTHGATE.PV***	2003-Dec-30 08:16:28.983	***Sag *Exceeds Tolerance***	***V1***	***0.8009999990***	***38.00***
Incident 5	SOUTHGATE.PV	2004-Jan-13 14:48:13.494	Sag	V3	0.8159999847	86.00
Incident 4	***Redlands.NGMT***	2003-Mar-04 01:56:12.721	***Sag *Exceeds Tolerance***	***V1***	***0.8169999719***	***61.00***
Incident 7	SOUTHGATE.PCC	2004-Apr-29 19:03:00.563	Sag	V1	0.8420000076	83.00
Incident 6	SOUTHGATE.PCC	2004-Jun-21 23:36:25.625	Sag	V1	0.8590000272	80.00
Incident 4	Redlands.PCC	2002-Sep-07 07:18:37.732	Sag	V1	0.8830000162	82.00
Incident 34	SOUTHGATE.PV	2004-May-06 13:47:11.855	Sag	V1	0.9419999719	86.00
Incident 33	SOUTHGATE.PV	2004-May-06 13:33:03.701	Sag	V1	0.9430000186	88.00
Incident 44	*Redlands.PCC*	2002-Nov-25 13:21:56.694	Sag *Exceeds Tolerance	V2	0.9750000238	16.00

C.17 Log of Server Sag RMS Events 1 to 2 sec

Incident ID	Monitor	Time Stamp	Event Type	Phase	Duration	Magnitude
Incident 37	SOUTHGATE.PV	2004-May-06 14:47:40.182	Sag	V1	1.0260000229	88.00
Incident 2	*SOUTHGATE.PCC*	2003-Nov-09 08:49:53.509	Sag *Exceeds Tolerance	V1	1.0420000553	50.00
Incident 9	***SOUTHGATE.PV***	2003-Nov-12 15:13:06.887	***Sag *Exceeds Tolerance***	***V2***	***1.0920000076***	***63.00***
Incident 10	SOUTHGATE.PV	***2004-May-05 13:33:01.272***	***Sag***	***V1***	***1.4249999523***	***86.00***

C.18 Log of Server Sag RMS Events 2 to 3 sec

Incident ID	Monitor	Time Stamp	Event Type	Phase	Duration	Magnitude
Incident 31	SOUTHGATE.PV	2004-May-06 13:25:56.270	Sag	V1	2.4249999523	86.00
Incident 40	SOUTHGATE.PV	2004-May-06 15:17:25.991	Sag	V1	2.4930000305	86.00
Incident 5	SOUTHGATE.PV	***2004-Jul-20 12:51:43.389***	***Sag***	***V1***	***2.7999999523***	***88.00***

C.19 Log of Server Sag RMS Events 10 to 50 sec

Incident ID	Monitor	Time Stamp	Event Type	Phase	Duration	Magnitude
Incident 3	SOUTHGATE.PCC	***2004-Jul-20 12:50:03.471***	***Sag***	***V1***	***46.5900001526***	***86.00***

C.20 Log of Server Swell RMS Events Summary

Duration	106	107	108	109	110	Totals
1 c	57	6				63
2 c	8					8
3 c	4					4
4 c						0
5 c	1					1
5 to 10 c	4					4
10 to 20 c	1	1				2
20 to 30 c	1					1
30 to 60 c	2					2
2 s	1	2				3
3 s	5	1				6
4 s		2				2
5 s						0
5 to 10 s	5	5	1			11
10 to 25 s		2	1			3
25 to 50 s	2	26	1			29
50 to 100 s		15	8	1		24
Totals	91	60	11	1	0	163

C.21 Log of Server Swell RMS Events 0 to 1 cycle

Incident ID	Monitor	Time Stamp	Event Type	Phase	Duration	Magnitude
Incident 100	SanDiego.NGIC	2004-Aug-25 21:13:38.883	Swell	V1	0.00800000	106.00
Incident 2	SanDiego.NGIC	2004-Oct-01 08:11:59.434	Swell	V1	0.00800000	106.00
Incident 7	SanDiego.NGIC	2004-Oct-04 18:54:00.576	Swell	V1	0.00800000	106.00
Incident 41	SanDiego.NGIC	2004-Oct-17 09:42:07.482	Swell	V1	0.00800000	106.00
Incident 52	SanDiego.NGIC	2004-Oct-19 18:21:19.883	Swell	V1	0.00800000	106.00
Incident 25	SanDiego.PCC	2004-Aug-11 17:05:56.109	Swell	V1	0.00800000	106.00
Incident 106	SanDiego.PCC	2004-Aug-24 08:02:54.353	Swell	V1	0.00800000	106.00
Incident 115	SanDiego.PCC	2004-Aug-27 05:21:20.895	Swell	V1	0.00800000	106.00
Incident 42	SanDiego.PCC	2004-Sep-21 19:00:29.446	Swell	V1	0.00800000	106.00
Incident 10	SanDiego.PCC	2004-Oct-04 21:07:06.924	Swell	V1	0.00800000	106.00
Incident 50	SanDiego.PCC	2004-Oct-20 21:15:32.214	Swell	V1	0.00800000	106.00
Incident 5	~~LosAngeles.MT1~~LosAngeles.NGMT1	2004-Feb-06 08:35:15.088	Swell	V3	0.00800000	106.00
Incident 3	~~LosAngeles.MT3~~LosAngeles.NGMT3	2004-Feb-06 08:27:15.533	Swell	V3	0.00800000	106.00
Incident 6	~~LosAngeles.MT3~~LosAngeles.NGMT3	2004-Feb-06 08:28:19.296	Swell	V3	0.00800000	106.00
Incident 12	~~LosAngeles.MT3~~LosAngeles.NGMT3	2004-Feb-06 08:33:34.346	Swell	V3	0.00800000	106.00
Incident 15	~~LosAngeles.MT3~~LosAngeles.NGMT3	2004-Feb-06 08:37:55.299	Swell	V3	0.00800000	106.00
Incident 16	~~LosAngeles.MT3~~LosAngeles.NGMT3	2004-Feb-06 08:49:13.347	Swell	V3	0.00800000	106.00
Incident 4	SanDiego.NGIC	2003-May-06 19:41:33.366	Swell	V1	0.00800000	106.00
Incident 17	SanDiego.NGIC	2003-Jun-17 08:14:42.390	Swell	V1	0.00800000	106.00
Incident 45	SanDiego.NGIC	2003-Sep-23 19:09:45.418	Swell	V1	0.00800000	106.00
Incident 17	SanDiego.NGIC	2003-Oct-06 10:22:23.439	Swell	V1	0.00800000	106.00
Incident 25	SanDiego.NGIC	2003-Nov-08 21:16:47.244	Swell	V1	0.00800000	106.00
Incident 102	SanDiego.NGIC	2004-Jan-29 21:30:03.371	Swell	V1	0.00800000	106.00
Incident 43	SanDiego.NGIC	2004-Feb-25 14:04:36.464	Swell	V1	0.00800000	106.00
Incident 19	SanDiego.NGIC	2004-Mar-04 12:37:53.367	Swell	V1	0.00800000	106.00
Incident 95	SanDiego.NGIC	2004-Mar-31 10:24:16.211	Swell	V1	0.00800000	106.00
Incident 18	SanDiego.NGIC	2004-Apr-07 20:11:25.732	Swell	V1	0.00800000	106.00
Incident 31	SanDiego.NGIC	2004-Apr-13 20:52:57.093	Swell	V1	0.00800000	106.00
Incident 5	SanDiego.PCC	2003-May-07 20:09:06.779	Swell	V1	0.00800000	106.00
Incident 25	SanDiego.PCC	2003-May-22 20:10:22.059	Swell	V1	0.00800000	106.00
Incident 16	SanDiego.PCC	2003-Jun-17 20:32:33.099	Swell	V1	0.00800000	106.00
Incident 2	SanDiego.PCC	2003-Jul-01 15:06:14.896	Swell	V1	0.00800000	106.00
Incident 40	SanDiego.PCC	2003-Sep-19 09:17:43.408	Swell	V1	0.00800000	106.00
Incident 39	SanDiego.PCC	2003-Oct-09 18:48:24.643	Swell	V1	0.00800000	106.00

Incident ID	Monitor	Time Stamp	Event Type	Phase	Duration	Magnitude
Incident 115	SanDiego.PCC	2003-Oct-30 10:10:48.656	Swell	V1	0.00800000	106.00
Incident 64	SanDiego.PCC	2003-Dec-23 09:05:31.865	Swell	V1	0.00800000	106.00
Incident 78	SanDiego.PCC	2003-Dec-24 14:48:41.004	Swell	V1	0.00800000	106.00
Incident 10	SanDiego.PCC	2004-Jan-09 07:17:28.878	Swell	V1	0.00800000	106.00
Incident 74	SanDiego.PCC	2004-Jan-20 18:01:25.324	Swell	V1	0.00800000	106.00
Incident 65	SanDiego.PCC	2004-Feb-26 20:22:00.991	Swell	V1	0.00800000	106.00
Incident 70	SanDiego.PCC	2004-Feb-27 17:56:53.697	Swell	V1	0.00800000	106.00
Incident 1	SanDiego.PCC	2004-Mar-01 07:12:07.414	Swell	V1	0.00800000	106.00
Incident 36	SanDiego.PCC	2004-Mar-05 09:18:37.479	Swell	V1	0.00800000	106.00
Incident 55	SanDiego.PCC	2004-Mar-09 18:07:10.282	Swell	V1	0.00800000	106.00
Incident 28	SanDiego.PCC	2004-Apr-12 19:39:08.221	Swell	V1	0.00800000	106.00
Incident 32	SanDiego.NGIC	2003-Jun-25 08:38:52.808	Swell	V1	0.00800000	107.00
Incident 33	SanDiego.NGIC	2003-Nov-09 16:58:13.216	Swell	V1	0.00800000	107.00
Incident 89	SanDiego.NGIC	2003-Dec-30 17:34:08.570	Swell	V1	0.00800000	107.00
Incident 9	SanDiego.NGIC	2004-Jan-08 08:04:28.206	Swell	V1	0.00800000	107.00
Incident 15	SanDiego.NGIC	2004-Apr-06 19:29:08.129	Swell	V1	0.00800000	107.00
Incident 1	SanDiego.PCC	2003-Mar-01 18:21:19.614	Swell	V1	0.00800000	107.00
Incident 11	SanDiego.NGIC	2004-Sep-03 06:24:59.473	Swell	V1	0.01600000	106.00
Incident 91	SanDiego.PCC	2004-Aug-21 09:06:26.082	Swell	V1	0.01600000	106.00
Incident 3	LOSANGELES.FC	2004-Feb-06 08:32:21.761	Swell	V3	0.01600000	106.00
Incident 40	SanDiego.NGIC	2003-Oct-10 05:32:16.270	Swell	V1	0.01600000	106.00
Incident 9	SanDiego.PCC	2003-May-12 09:31:11.096	Swell	V1	0.01600000	106.00
Incident 44	SanDiego.PCC	2003-May-31 11:27:36.769	Swell	V1	0.01600000	106.00
Incident 58	SanDiego.PCC	2003-Sep-26 15:15:27.358	Swell	V1	0.01600000	106.00
Incident 34	SanDiego.PCC	2003-Oct-07 13:28:58.418	Swell	V1	0.01600000	106.00
Incident 103	SanDiego.PCC	2003-Oct-28 10:25:19.496	Swell	V1	0.01600000	106.00
Incident 7	SanDiego.PCC	2003-Dec-03 16:44:28.490	Swell	V1	0.01600000	106.00
Incident 38	SanDiego.PCC	2004-Jan-14 17:37:15.483	Swell	V1	0.01600000	106.00
Incident 61	SanDiego.PCC	2004-Jan-15 18:29:54.538	Swell	V1	0.01600000	106.00

C.22 Log of Server Swell RMS Events 1 to 2 cycle

Incident ID	Monitor	Time Stamp	Event Type	Phase	Duration	Magnitude
Incident 79	SanDiego.NGIC	2004-Sep-28 08:42:34.244	Swell	V1	0.02400000	106.00
Incident 5	SanDiego.NGIC	2003-Mar-06 09:10:46.047	Swell	V1	0.02500000	106.00
Incident 71	SanDiego.NGIC	2003-Sep-27 19:31:01.479	Swell	V1	0.03300000	106.00
Incident 84	SanDiego.NGIC	2003-Sep-27 21:21:35.402	Swell	V1	0.03300000	106.00
Incident 55	SanDiego.NGIC	2004-Jan-16 18:00:41.745	Swell	V1	0.03300000	106.00
Incident 13	SanDiego.NGIC	2004-Mar-04 08:39:17.473	Swell	V1	0.03300000	106.00
Incident 76	SanDiego.NGIC	2004-Apr-13 21:53:02.773	Swell	V1	0.03300000	106.00
Incident 96	SanDiego.PCC	2003-Dec-31 17:59:26.394	Swell	V1	0.03300000	106.00

C.23 Log of Server Swell RMS Events 2 to 3 cycle

Incident ID	Monitor	Time Stamp	Event Type	Phase	Duration	Magnitude
Incident 16	SanDiego.NGIC	2004-Jan-12 07:15:01.233	Swell	V1	0.04100000	106.00
Incident 72	SanDiego.NGIC	2004-Jan-22 13:42:47.473	Swell	V1	0.04100000	106.00
Incident 93	SanDiego.NGIC	2004-Apr-22 20:01:43.451	Swell	V1	0.04100000	106.00
Incident 50	SanDiego.PCC	2003-Dec-19 16:55:10.492	Swell	V1	0.04100000	106.00

C.24 Log of Server Swell RMS Events 4 to 5 cycle

Incident ID	Monitor	Time Stamp	Event Type	Phase	Duration	Magnitude
Incident 83	SanDiego.NGIC	2004-Mar-31 07:47:17.956	Swell	V1	0.08300000	106.00

C.25 Log of Server Swell RMS Events 5 to 10 cycle

Incident ID	Monitor	Time Stamp	Event Type	Phase	Duration	Magnitude
Incident 33	SanDiego.NGIC	2004-Jun-10 10:10:14.783	Swell	V1	0.10800000	106.00
Incident 12	SanDiego.PCC	2003-Apr-11 11:25:55.488	Swell	V1	0.10800000	106.00
Incident 5	SanDiego.PCC	2003-Nov-04 17:32:41.670	Swell	V1	0.11700000	106.00
Incident 88	SanDiego.NGIC	2004-Apr-19 21:01:00.403	Swell	V1	0.13300000	106.00

C.26 Log of Server Swell RMS Events 10 to 20 cycle

Incident ID	Monitor	Time Stamp	Event Type	Phase	Duration	Magnitude
Incident 14	SanDiego.PCC	2003-Dec-04 17:12:18.278	Swell	V1	0.25000000	106.00
Incident 4	SouthGate.PV	2003-Mar-16 20:21:16.809	Swell	V3	0.29699999	107.00

C.27 Log of Server Swell RMS Events 20 to 30 cycle

Incident ID	Monitor	Time Stamp	Event Type	Phase	Duration	Magnitude
Incident 1	SanDiego.NGIC	2004-Apr-01 07:52:49.258	Swell	V1	0.42600000	106.00

C.28 Log of Server Swell RMS Events 30 to 60 cycle

Incident ID	Monitor	Time Stamp	Event Type	Phase	Duration	Magnitude
Incident 101	SanDiego.PCC	2004-Jan-26 16:19:29.394	Swell	V1	0.52499998	106.00
Incident 11	SanDiego.PCC	2004-Feb-06 06:24:00.271	Swell	V1	0.79200000	106.00

C.29 Log of Server Swell RMS Events 1 to 2 sec

Incident ID	Monitor	Time Stamp	Event Type	Phase	Duration	Magnitude
Incident 37	SanDiego.PCC	2003-Aug-29 09:55:23.998	Swell	V1	1.17499995	107.00
Incident 60	SanDiego.PCC	2004-Mar-12 14:16:38.648	Swell	V1	1.31700003	107.00
Incident 67	SanDiego.PCC	2004-Mar-19 10:21:06.467	Swell	V1	1.39100003	106.00

C.30 Log of Server Swell RMS Events 2 to 3 sec

Incident ID	Monitor	Time Stamp	Event Type	Phase	Duration	Magnitude
Incident 1	SanDiego.PCC	2004-Jul-01 13:51:56.022	Swell	V1	2.26600003	106.00
Incident 121	SanDiego.PCC	2003-Oct-31 11:11:19.930	Swell	V1	2.49200010	106.00
Incident 27	SanDiego.PCC	2003-Dec-15 16:21:47.167	Swell	V1	2.51699996	106.00
Incident 90	SanDiego.NGIC	2004-Mar-31 09:44:54.486	Swell	V1	2.56800008	106.00
Incident 38	SanDiego.NGIC	2003-Dec-17 17:02:00.505	Swell	V1	2.79299998	107.00
Incident 37	SanDiego.PCC	2004-May-20 21:01:09.638	Swell	V1	2.83299994	106.00

C.31 Log of Server Swell RMS Events 3 to 4 sec

Incident ID	Monitor	Time Stamp	Event Type	Phase	Duration	Magnitude
Incident 53	SanDiego.PCC	2004-Feb-25 18:05:21.589	Swell	V1	3.57500005	107.00
Incident 33	SanDiego.PCC	2003-May-25 20:01:30.402	Swell	V1	3.74099994	107.00

C.32 Log of Server Swell RMS Events 5 to 10 sec

Incident ID	Monitor	Time Stamp	Event Type	Phase	Duration	Magnitude
Incident 49	SanDiego.NGIC	2004-Aug-19 09:26:35.083	Swell	V1	5.56099987	106.00
Incident 2	LosAngeles.MT2	2003-Jul-21 08:36:25.046	Swell	V3	6.20699978	107.00
Incident 4	LOSANGELES.FC	2004-Apr-27 07:42:05.294	Swell	V3	6.36700010	107.00
Incident 58	SanDiego.PCC	2004-Aug-18 05:47:36.091	Swell	V1	7.12099981	106.00
Incident 30	SanDiego.PCC	2004-May-19 20:26:33.562	Swell	V1	7.23500013	106.00
Incident 83	SanDiego.PCC	2004-Jan-22 08:55:17.683	Swell	V1	7.75899982	107.00
Incident 11	SanDiego.PCC	2003-Oct-05 10:15:35.223	Swell	V1	7.82999992	106.00
Incident 19	SanDiego.PCC	2003-Jun-18 20:20:33.581	Swell	V1	7.86000013	108.00
Incident 72	SanDiego.PCC	2003-Dec-24 07:26:51.755	Swell	V1	8.51700020	107.00
Incident 81	SanDiego.PCC	2004-Jul-28 23:24:53.718	Swell	V1	8.54100037	106.00
Incident 24	SanDiego.PCC	2004-Oct-09 18:55:12.417	Swell	V1	8.96199989	107.00

C.33 Log of Server Swell RMS Events 10 to 25 sec

Incident ID	Monitor	Time Stamp	Event Type	Phase	Duration	Magnitude
Incident 19	SanDiego.NGIC	2004-Jun-03 20:06:44.975	Swell	V1	21.46400070	107.00
Incident 34	SanDiego.NGIC	2003-Dec-16 17:00:57.119	Swell	V1	22.53599930	108.00
Incident 76	SanDiego.NGIC	2004-Jun-29 20:05:51.456	Swell	V1	24.91200066	107.00

C.34 Log of Server Swell RMS Events 25 to 50 sec

Incident ID	Monitor	Time Stamp	Event Type	Phase	Duration	Magnitude
Incident 24	SanDiego.NGIC	2004-Feb-14 22:03:30.398	Swell	V1	25.01300049	107.00
Incident 45	SanDiego.NGIC	2004-May-21 21:25:46.956	Swell	V1	30.38999939	106.00
Incident 5	SanDiego.NGIC	2004-Sep-02 06:13:45.196	***Swell***	***V1***	***32.51499939***	***107.00***
Incident 10	SanDiego.NGIC	2004-Jun-02 20:24:15.391	Swell	V1	35.72999954	107.00
Incident 27	SanDiego.NGIC	2004-Jan-13 17:40:41.823	Swell	V1	37.42900085	107.00
Incident 37	SanDiego.PCC	2004-Jul-14 20:27:33.392	Swell	V1	38.85599899	107.00
Incident 90	SanDiego.PCC	2003-Sep-28 19:09:25.916	Swell	V1	39.30199814	107.00
Incident 52	SanDiego.NGIC	2004-Jul-17 18:37:56.448	Swell	V1	40.03200150	107.00
Incident 51	SanDiego.PCC	2004-Jun-28 20:13:51.174	Swell	V1	40.04100037	107.00
Incident 17	SanDiego.PCC	2004-Aug-09 20:23:57.324	Swell	V1	42.74800110	107.00
Incident 4	SanDiego.PCC	2003-Dec-02 21:17:59.623	Swell	V1	43.02099991	107.00
Incident 8	SanDiego.PCC	2004-Mar-03 10:50:24.945	Swell	V1	43.92300034	107.00
Incident 52	SanDiego.PCC	2003-Aug-31 15:04:23.900	Swell	V1	43.97399902	107.00
Incident 55	SanDiego.NGIC	2004-Jul-18 14:01:23.158	Swell	V1	44.33000183	107.00
Incident 46	SanDiego.PCC	2003-Oct-10 18:45:52.150	Swell	V1	45.62300110	107.00
Incident 17	SanDiego.PCC	2004-Feb-06 08:45:39.862	Swell	V1	45.78099823	107.00
Incident 3	SanDiego.PCC	2004-Feb-01 20:32:30.895	Swell	V1	45.84099960	106.00
Incident 42	SanDiego.NGIC	2003-Nov-17 11:28:08.635	Swell	V1	45.88999939	107.00
Incident 49	SanDiego.NGIC	2004-Aug-17 10:36:30.133	Swell	V1	46.24399948	107.00
Incident 57	SanDiego.NGIC	2003-Dec-21 16:37:28.081	Swell	V1	46.36000061	107.00
Incident 96	SanDiego.NGIC	2004-Jul-31 23:06:35.961	Swell	V1	46.78200150	107.00
Incident 24	SanDiego.NGIC	2004-Apr-11 20:59:28.980	Swell	V1	47.11500168	107.00
Incident 94	SanDiego.NGIC	2004-Aug-23 19:41:30.078	Swell	V1	47.23199844	107.00
Incident 61	SanDiego.PCC	2004-Feb-26 13:57:10.704	Swell	V1	47.97299957	107.00
Incident 45	SanDiego.PCC	2004-Aug-13 20:05:40.085	Swell	V1	48.27999878	108.00
Incident 32	SanDiego.NGIC	2003-Oct-09 06:18:30.399	Swell	V1	48.53799820	107.00
Incident 95	SanDiego.PCC	2004-Sep-30 09:36:56.256	Swell	V1	48.92300034	107.00
Incident 14	SanDiego.PCC	2004-Apr-03 18:12:16.357	Swell	V1	48.96599960	107.00
Incident 88	SanDiego.PCC	2004-Sep-29 06:18:00.309	Swell	V1	49.35599899	107.00

C.35 Log of Server Swell RMS Events 50 to 100 sec

Incident ID	Monitor	Time Stamp	Event Type	Phase	Duration	Magnitude
Incident 32	SanDiego.PCC	2003-Oct-07 13:25:29.323	Swell	V1	50.44800186	107.00
Incident 62	SanDiego.NGIC	2004-Sep-24 19:03:58.325	Swell	V1	50.62200165	107.00
Incident 66	SanDiego.NGIC	2004-Sep-24 21:08:06.025	Swell	V1	50.64500046	107.00
Incident 31	SanDiego.NGIC	2003-Sep-16 04:51:56.404	Swell	V1	51.29399872	107.00
Incident 56	SanDiego.PCC	2004-Jan-15 17:32:12.872	Swell	V1	51.56000137	107.00
Incident 110	SanDiego.NGIC	2004-Aug-29 19:47:47.332	Swell	V1	51.64300156	107.00
Incident 41	SanDiego.PCC	2004-Aug-12 21:20:34.633	Swell	V1	51.95299911	107.00
Incident 36	SanDiego.PCC	2004-Aug-11 21:13:24.154	Swell	V1	52.22299957	107.00
Incident 113	SanDiego.PCC	2004-Aug-26 19:41:54.679	Swell	V1	52.51800156	107.00
Incident 23	SanDiego.NGIC	2004-Jan-12 21:19:00.532	Swell	V1	53.32099915	108.00
Incident 33	SanDiego.PCC	2004-Jul-12 20:17:56.396	Swell	V1	53.35599899	107.00
Incident 8	SanDiego.PCC	2004-Feb-05 06:27:43.516	Swell	V1	53.44900131	108.00
Incident 69	SanDiego.PCC	2003-Oct-20 18:43:18.604	Swell	V1	53.87599945	107.00
Incident 50	SanDiego.PCC	2004-Mar-08 18:23:16.941	Swell	V1	53.92300034	107.00
Incident 63	SanDiego.NGIC	2004-Feb-26 21:28:44.152	Swell	V1	53.94900131	107.00
Incident 30	SanDiego.PCC	2004-Apr-13 09:18:55.186	Swell	V1	54.00400162	107.00
Incident 46	SanDiego.NGIC	2003-Sep-23 19:09:53.093	Swell	V1	54.72900009	108.00
Incident 20	SanDiego.NGIC	2004-Jan-12 19:13:32.350	Swell	V1	55.99800110	108.00
Incident 22	SanDiego.PCC	2004-Aug-10 21:08:32.069	Swell	V1	58.71200180	107.00
Incident 80	SanDiego.PCC	2003-Oct-22 18:49:07.418	Swell	V1	61.13600159	109.00
Incident 56	SanDiego.NGIC	2004-Jan-16 18:00:42.845	Swell	V1	61.34400177	108.00
Incident 31	SanDiego.PCC	2003-Dec-15 19:14:17.761	Swell	V1	62.02700043	108.00
Incident 47	SanDiego.PCC	2004-Feb-24 18:38:31.259	Swell	V1	63.68099976	108.00
Incident 74	SanDiego.PCC	2003-Oct-21 18:40:33.211	Swell	V1	65.18800354	108.00

APPENDIX D: TOTAL HARMONIC DISTORTION SUMMARY

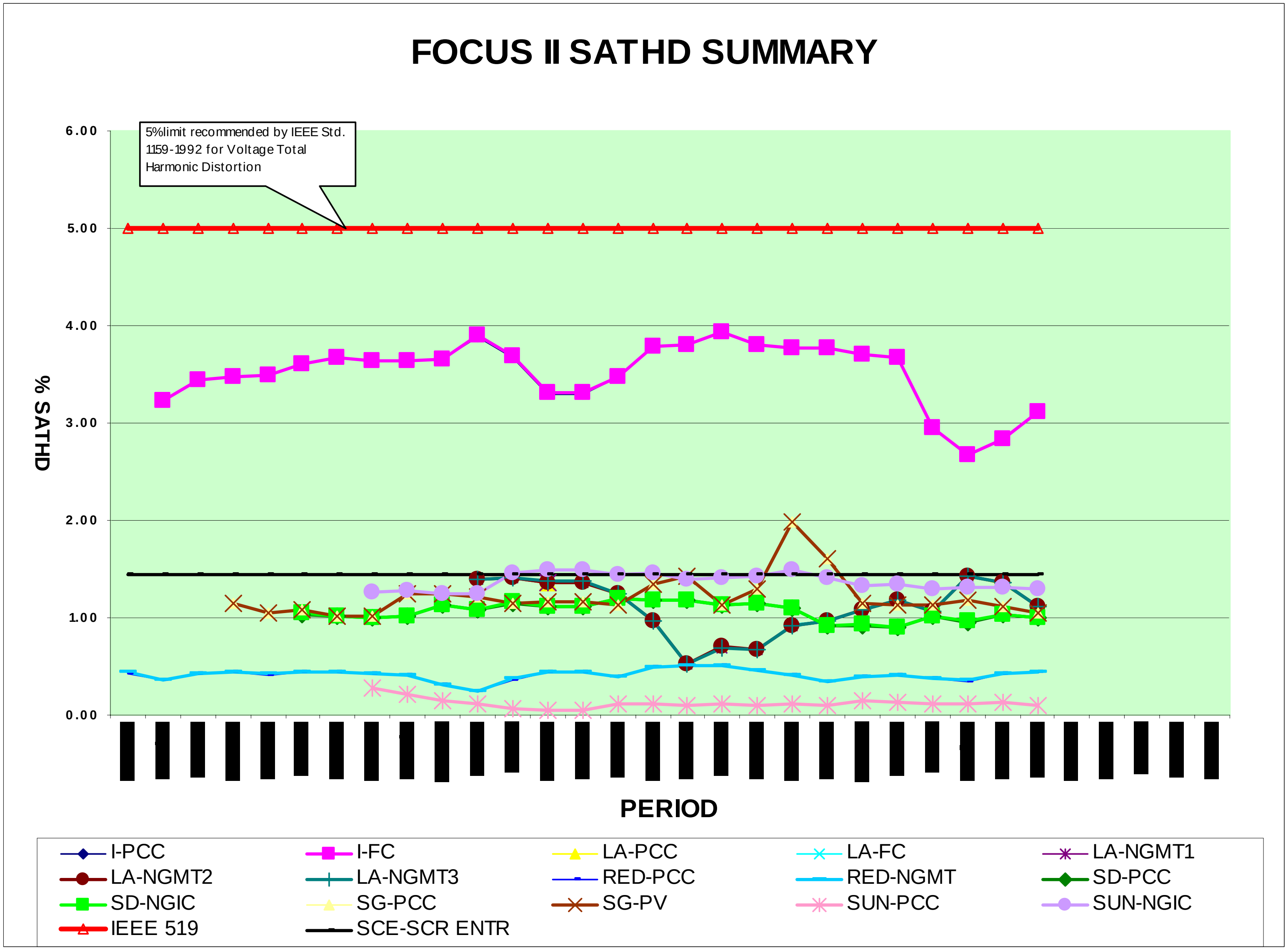
Appendix D – Total Harmonic Distortion Summary

D.1 Project SATHD by Month (Table)

SATHD Period	I PCC[1]	I FC	LA PCC	LA FC	LA NGMT1	LA NGMT2	LA NGMT3	RED PCC	RED NGMT	SD PCC	SD NGIC	SG PCC	SG PV	SUN PCC	SUN NGIC
Aug-02								0.42	0.45						
Sep-02	3.24	3.23						0.36	0.36						
Oct-02	3.44	3.44						0.42	0.42						
Nov-02	3.48	3.48						0.44	0.44			1.15	1.15		
Dec-02	3.49	3.49						0.42	0.42			1.05	1.06		
Jan-03	3.60	3.60						0.44	0.44	1.04	1.04	1.08	1.08		
Feb-03	3.66	3.67						0.45	0.45	1.02	1.02	1.01	1.01		
Mar-03	3.64	3.64						0.43	0.43	1.01	1.01	1.02	1.02	0.28	1.27
Apr-03	3.64	3.64						0.40	0.40	1.01	1.02	1.25	1.25	0.21	1.28
May-03	3.66	3.66						0.32	0.32	1.13	1.14	1.24	1.24	0.16	1.25
Jun-03	3.89	3.89	1.39	1.40	1.40	1.39	1.39	0.24	0.24	1.09	1.09	1.21	1.21	0.11	1.25
Jul-03	3.68	3.68	1.40	1.41	1.40	1.40	1.40	0.37	0.37	1.16	1.16	1.15	1.15	0.06	1.45
Aug-03	3.30	3.30	1.37	1.37	1.37	1.37	1.37	0.45	0.45	1.11	1.12	1.16	1.16	0.05	1.50
Sep-03	3.30	3.30	1.37	1.37	1.37	1.37	1.37	0.45	0.45	1.11	1.12	1.16	1.16	0.05	1.50
Oct-03	3.48	3.48	1.25	1.25	1.25	1.25	1.25	0.40	0.40	1.20	1.20	1.14	1.14	0.12	1.44
Nov-03	3.79	3.79	0.97	0.98	0.97	0.97	0.97	0.50	0.50	1.17	1.17	1.34	1.34	0.11	1.46
Dec-03	3.81	3.81	0.52	0.52	0.52	0.52	0.52	0.51	0.51	1.18	1.18	1.43	1.43	0.10	1.40
Jan-04	3.93	3.93	0.70	0.70	0.70	0.70	0.70	0.51	0.51	1.14	1.14	1.13	1.13	0.11	1.40
Feb-04	3.80	3.80	0.68	0.68	0.68	0.68	0.68	0.45	0.45	1.14	1.14	1.30	1.30	0.09	1.43
Mar-04	3.77	3.77	0.92	0.93	0.92	0.92	0.93	0.42	0.41	1.10	1.10	1.98	1.98	0.11	1.49
Apr-04	3.77	3.77	0.97	0.97	0.97	0.97	0.97	0.35	0.35	0.91	0.91	1.61	1.61	0.10	1.41
May-04	3.70	3.70	1.08	1.08	1.08	1.08	1.08	0.39	0.39	0.93	0.93	1.16	1.16	0.15	1.33
Jun-04	3.67	3.67	1.18	1.19	1.18	1.18	1.18	0.40	0.41	0.91	0.91	1.13	1.13	0.13	1.35
Jul-04	2.95	2.95	1.07	1.07	1.07	1.07	1.07	0.38	0.38	1.02	1.02	1.13	1.13	0.11	1.29
Aug-04	2.68	2.68	1.42	1.42	1.42	1.42	1.42	0.35	0.35	0.96	0.96	1.19	1.19	0.12	1.31
Sep-04	2.83	2.83	1.35	1.36	1.35	1.35	1.35	0.43	0.42	1.03	1.03	1.11	1.11	0.14	1.32
Oct-04	3.11	3.11	1.12	1.12	1.12	1.12	1.12	0.45	0.45	1.00	1.01	1.06	1.06	0.10	1.30
Total Average	3.51	3.51	1.10	1.11	1.10	1.10	1.10	0.41	0.41	1.06	1.06	1.22	1.22	0.12	1.37

[1] I = Irvine, LA = Los Angeles, Red = Redlands, SD = San Diego, SG = South Gate & SUN = Sunnyvale

D.2 Project SATHD by Month (Chart)

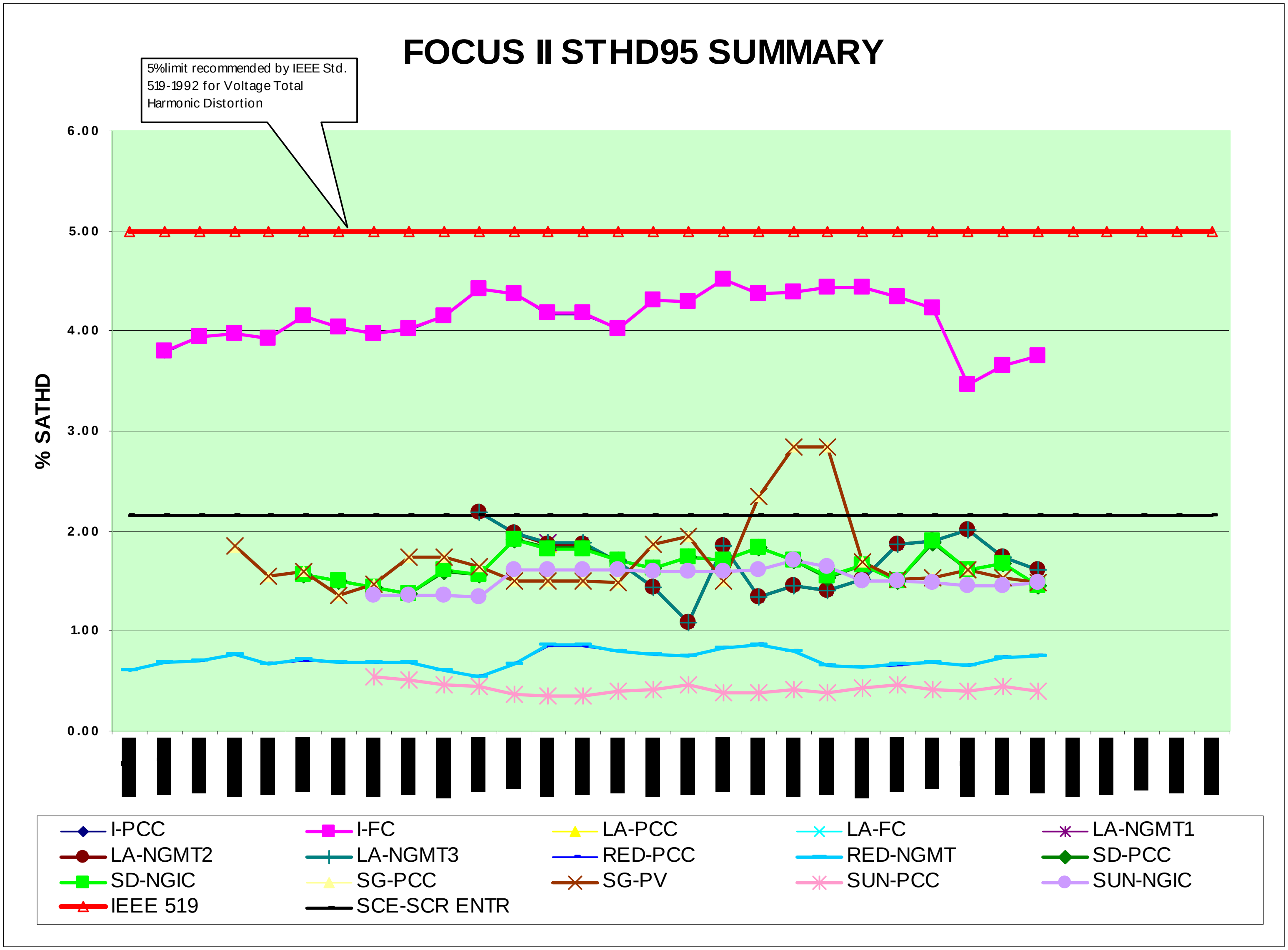


D.3 Project $STHD_{95}$ by Month (Table)

$STHD_{95}$ Period	I PCC [2]	I FC	LA PCC	LA FC	LA NGMT1	LA NGMT2	LA NGMT3	RED PCC	RED NGMT	SD PCC	SD NGIC	SG PCC	SG PV	SUN PCC	SUN NGIC
Aug-02								0.60	0.60						
Sep-02	3.79	3.79						0.68	0.68						
Oct-02	3.94	3.94						0.70	0.70						
Nov-02	3.98	3.98						0.77	0.77			1.84	1.84		
Dec-02	3.92	3.92						0.67	0.67			1.54	1.54		
Jan-03	4.15	4.15						0.71	0.71	1.56	1.57	1.59	1.59		
Feb-03	4.04	4.04						0.69	0.69	1.50	1.50	1.35	1.35		
Mar-03	3.98	3.98						0.69	0.69	1.44	1.44	1.47	1.47	0.54	1.35
Apr-03	4.01	4.01						0.69	0.69	1.37	1.37	1.73	1.73	0.51	1.36
May-03	4.15	4.15						0.60	0.61	1.60	1.60	1.75	1.75	0.46	1.35
Jun-03	4.42	4.43	2.19	2.19	2.19	2.19	2.19	0.54	0.54	1.57	1.57	1.65	1.65	0.45	1.34
Jul-03	4.37	4.37	1.98	1.98	1.98	1.98	1.98	0.66	0.67	1.92	1.91	1.50	1.50	0.36	1.61
Aug-03	4.17	4.17	1.87	1.88	1.88	1.87	1.88	0.85	0.86	1.83	1.83	1.50	1.50	0.35	1.61
Sep-03	4.17	4.17	1.87	1.88	1.88	1.87	1.88	0.85	0.86	1.83	1.83	1.50	1.50	0.35	1.61
Oct-03	4.02	4.03	1.69	1.69	1.69	1.69	1.69	0.79	0.79	1.70	1.70	1.48	1.48	0.40	1.61
Nov-03	4.30	4.30	1.44	1.45	1.44	1.44	1.44	0.76	0.76	1.62	1.62	1.87	1.87	0.41	1.60
Dec-03	4.29	4.29	1.08	1.08	1.08	1.08	1.08	0.75	0.75	1.74	1.74	1.95	1.95	0.46	1.59
Jan-04	4.51	4.51	1.85	1.86	1.86	1.86	1.85	0.83	0.83	1.71	1.71	1.51	1.50	0.38	1.60
Feb-04	4.37	4.37	1.34	1.34	1.34	1.34	1.34	0.86	0.86	1.83	1.83	2.34	2.34	0.38	1.62
Mar-04	4.39	4.39	1.45	1.45	1.45	1.45	1.45	0.80	0.80	1.71	1.71	2.85	2.85	0.41	1.71
Apr-04	4.44	4.44	1.41	1.41	1.41	1.41	1.41	0.66	0.66	1.54	1.54	2.84	2.84	0.39	1.65
May-04	4.43	4.43	1.51	1.52	1.52	1.51	1.51	0.64	0.64	1.66	1.66	1.70	1.70	0.44	1.50
Jun-04	4.33	4.33	1.86	1.87	1.86	1.86	1.86	0.66	0.66	1.51	1.51	1.51	1.51	0.46	1.50
Jul-04	4.22	4.22	1.90	1.90	1.90	1.90	1.90	0.68	0.68	1.89	1.89	1.54	1.54	0.42	1.48
Aug-04	3.46	3.46	2.01	2.02	2.02	2.02	2.02	0.66	0.66	1.61	1.62	1.61	1.61	0.40	1.45
Sep-04	3.66	3.66	1.74	1.74	1.74	1.74	1.74	0.74	0.74	1.67	1.67	1.53	1.53	0.45	1.45
Oct-04	3.74	3.74	1.61	1.61	1.61	1.61	1.61	0.74	0.74	1.46	1.46	1.49	1.48	0.40	1.48
Total Average	4.13	4.13	1.70	1.70	1.70	1.70	1.70	0.71	0.71	1.65	1.65	1.73	1.73	0.42	1.52

[2] I = Irvine, LA = Los Angeles, Red = Redlands, SD = San Diego, SG = South Gate & SUN = Sunnyvale

D.4 Project $STHD_{95}$ by Month (Chart)

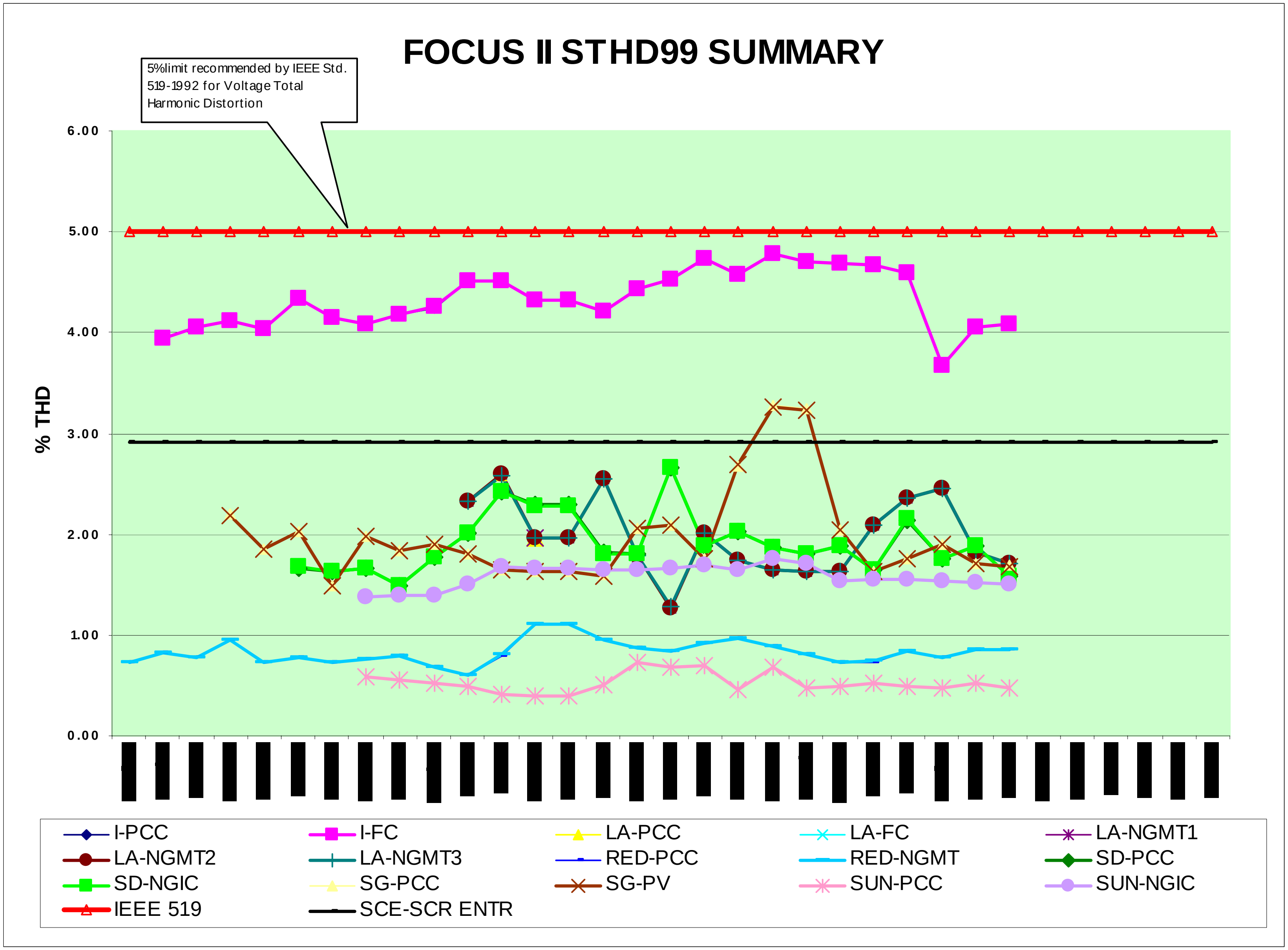


D.5 Project $STHD_{99}$ by Month (Table)

$STHD_{99}$ Period	I PCC [3]	I FC	LA PCC	LA FC	LA NGMT1	LA NGMT2	LA NGMT3	RED PCC	RED NGMT	SD PCC	SD NGIC	SG PCC	SG PV	SUN PCC	SUN NGIC
Aug-02								0.72	0.73						
Sep-02	3.95	3.94						0.82	0.82						
Oct-02	4.05	4.05						0.78	0.78						
Nov-02	4.11	4.11						0.95	0.94			2.20	2.19		
Dec-02	4.03	4.04						0.73	0.73			1.86	1.86		
Jan-03	4.34	4.34						0.77	0.77	1.66	1.67	2.02	2.02		
Feb-03	4.14	4.14						0.73	0.73	1.63	1.63	1.48	1.48		
Mar-03	4.09	4.09						0.76	0.76	1.66	1.66	1.97	1.98	0.58	1.38
Apr-03	4.18	4.19						0.79	0.79	1.48	1.48	1.84	1.84	0.56	1.39
May-03	4.25	4.25						0.67	0.67	1.78	1.78	1.89	1.89	0.52	1.39
Jun-03	4.52	4.52	2.32	2.32	2.32	2.32	2.32	0.60	0.61	2.01	2.01	1.80	1.80	0.50	1.51
Jul-03	4.52	4.52	2.58	2.59	2.59	2.59	2.58	0.80	0.80	2.42	2.42	1.65	1.65	0.42	1.67
Aug-03	4.33	4.33	1.97	1.97	1.97	1.97	1.97	1.10	1.10	2.29	2.29	1.63	1.63	0.39	1.67
Sep-03	4.33	4.33	1.97	1.97	1.97	1.97	1.97	1.10	1.10	2.29	2.29	1.63	1.63	0.39	1.67
Oct-03	4.21	4.21	2.55	2.55	2.55	2.55	2.55	0.95	0.95	1.81	1.81	1.59	1.59	0.50	1.64
Nov-03	4.43	4.43	1.79	1.79	1.78	1.79	1.79	0.87	0.87	1.80	1.80	2.06	2.05	0.72	1.65
Dec-03	4.53	4.53	1.28	1.28	1.27	1.27	1.28	0.83	0.83	2.66	2.66	2.09	2.09	0.68	1.67
Jan-04	4.73	4.73	2.01	2.01	2.01	2.01	2.01	0.92	0.92	1.89	1.89	1.75	1.75	0.70	1.69
Feb-04	4.57	4.57	1.74	1.74	1.74	1.74	1.74	0.97	0.97	2.02	2.02	2.68	2.69	0.46	1.65
Mar-04	4.78	4.78	1.64	1.65	1.64	1.64	1.65	0.89	0.89	1.87	1.87	3.27	3.27	0.68	1.76
Apr-04	4.70	4.70	1.63	1.63	1.62	1.63	1.63	0.81	0.81	1.80	1.80	3.25	3.23	0.47	1.71
May-04	4.69	4.69	1.63	1.63	1.63	1.64	1.64	0.72	0.73	1.88	1.88	2.05	2.05	0.49	1.54
Jun-04	4.67	4.67	2.09	2.09	2.09	2.09	2.09	0.73	0.74	1.64	1.64	1.64	1.63	0.52	1.55
Jul-04	4.60	4.60	2.35	2.36	2.35	2.35	2.36	0.83	0.84	2.14	2.15	1.76	1.76	0.49	1.55
Aug-04	3.67	3.67	2.45	2.45	2.45	2.45	2.45	0.78	0.78	1.76	1.76	1.89	1.90	0.47	1.54
Sep-04	4.06	4.06	1.83	1.82	1.83	1.83	1.83	0.85	0.85	1.89	1.89	1.71	1.71	0.53	1.52
Oct-04	4.09	4.09	1.70	1.70	1.70	1.71	1.70	0.85	0.85	1.59	1.59	1.69	1.69	0.47	1.51
Total Average	4.33	4.33	1.97	1.97	1.97	1.97	1.97	0.83	0.83	1.91	1.91	1.97	1.97	0.53	1.58

[3] I = Irvine, LA = Los Angeles, Red = Redlands, SD = San Diego, SG = South Gate & SUN = Sunnyvale

D.6 Project STHD$_{99}$ by Month (Chart)



APPENDIX E: ACTIVITY LOG

Appendix E – Activity Log

Date	Activity
4/1/02	**Overall Program Review** - The program now has adequate representation relative to Micro turbines, Fuel Cells and PV. **Site Selection Process** - During the 2nd Quarter 2002, the main task for the monitoring project is the site selection task. Interface meetings are held with Utilities, Municipalities and potential clients. Sites are selected, site surveys performed or scheduled. Instrumentation is ordered and being fabricated by Power Measurements (PM) with initial installation schedule for the 3rd Quarter 2002. **Monitoring Program Changes** - The monitoring program adapted changes to include the comments made by Utilities, particularly PG&E. The project will include monitors at both the DG and at the Point of Common Coupling (PCC). It will also include selection of more difficult sites and multiple DG sites; These changes have resulted in modifications to the site selection process and a different site selection mix. **Instrumentation Purchase Order -** Placed Purchase Order with PM for the ION 7600 System. The purchase order to PM followed a long evaluation period where two highly qualified bidders were in contention.
4/1/02	**Monitoring Program Changes** - The monitoring program adapted changes to include the comments made by Utilities, particularly PG&E. The project will include monitors at both the DG and at the Point of Common Coupling (PCC). It will also include selection of more difficult sites and multiple DG sites; These changes have resulted in modifications to the site selection process and a different site selection mix.
6/12/02	**Los Angeles Site**– Site Survey of a site that includes one Fuel Cell (250 kW) and Three Microturbines (120 kW) and will require 5 monitors.
6/27/02	**Irvine Site**– Site Survey of a site that includes one Fuel Cell (235 kW) and will require 2 monitors
6/30/02	**Site Selection Process** – The following sites are being evaluated as part of the Site Selection Process: o **SMUD** – One site with multiple PVs o **PG&E** – Six sites with different DG technologies o **Riverside** – One site o **SDG&E** – Two Microturbine sites (one synchronize and one nonsynchronize)
7/2/02	**Redlands Site**– Site Survey of a site that which includes two Microturbines (120 kW). The Microturbines are not yet in service and with be part of an AQMD project. It will be possible to install the monitoring system before the Microturbines are operational, thereby obtaining "before" and "after" monitoring to see how the DG impacts the system. This before-and-after picture will resolve one of PG&E's comments against the monitoring program plan.
7/8/02	**South Gate Site**– Site Survey of a site that includes one PV (14 kW) and

	will require 2 monitors
7/12/02	**2nd Quarterly Report** – Complete & issue Quarterly Report. Issue reports to program participants **Site Selection Process Challenges** - There continue to be challenges with finding the right contractual arrangement for the monitoring to take place. Each site has a different ownership structure with its own approval mechanism relative to instruments on its power system. In the case of the LADWP, for example, it is a municipal that is part of the city and must follow city ordnances and requirements. When dealing with a private company, the requirements may be quite different. Considerably greater contractual skills and effort are needed to handle their diverse circumstances. While the technical portion of the work is going somewhat according to the plan, the administrative aspects have required greater effort than previously considered necessary.
7/15/02 – 7/18/02	**ION Training** - Reflective Energies (Reflective) attends Training in Victoria, British Columbia, Canada o **ION Fundamentals** – This introductory course focuses on the fundamentals of ION meter communications and ION Enterprise software. After reviewing the fundamentals of ION technology, students will learn the basics for using and maximizing an ION Enterprise system. In a hands-on lab environment, students will be guided through a series of learning exercises to practice how to use an ION Enterprise system more effectively. o **ION Programmer -** This course focuses on meter level and system level programming using ION Designer™ and ION Setup software. After reviewing the basics of ION meter programming, students will learn to customize, build and manage ION application programs. In a hands-on lab environment, students will be guided through a series of exercises to practice programming different ION meters and the VIP™ (Virtual ION Processor).
8/26/02 – 10/14/02	**Redlands Site** – PM installs the ION 7600 equipment for the PCC and DG. The monitors are placed in operational 8/26/02. DSL is installed 10/14/02 and PM makes another visit to program the monitors, setup network parameters and activate DSL communications with the web server.
9/6/02	**ION Enterprise Software** - PM installs and configures ION Enterprise Software on Monitoring Program Server.
9/8/02 – 9/9/02	**Irvine Site** – PM installs the ION 7600 equipment for the PCC and DG. The monitors are placed in operational 9/8/02. At this site, the Fuel Cell runs continuously. On 9/9/02, Reflective makes a site visit to program the monitors, setup network parameters and activate DSL communications with the web server.
9/10/02	**South Gate Site** – PM installs the ION 7600 equipment for the PCC and DG. The monitors are placed in operational 9/10/02. The DSL line is schedule for installation 10/14/02. This is the first PV system so monitored.
9/13/02 – 9/26/02	**Redlands Site** – PCC communication is lost 9/13/02. This is the first occurrence of Ethergate Lockup when a communication error with PCC occurs and no data is downloading to the web server. PM performs troubleshooting to isolate the problem on 9/26/02 and replaces communication card, which restores operation of the PCC monitor.

9/27/02	**Web Server** - PM installs additional software, re-configures web server, installs and configures a Linksys router, and installs PM Web Reach. The web server is configured for a domain name http://68.5.129.61:81/ion/. Website is activated and placed in operation.
10/18/02	**3rd Quarterly Report** – Complete & issue Quarterly Report. Issue reports to program participants. **Web Server** – Reflective installs pcAnywhere on web server to allow PM the ability to help Reflective troubleshoot server related problems with ION Enterprise Software.
10/24/02	**Rule 21 Working Group Meetings**– Provided preview of web site at Rule 21 Meeting in Sacramento. Demonstrated the features of the ION Enterprise Software for Data Acquisition, Monitoring, Analysis & Reports
11/8/02	**Web Server** – SCE notifies Reflective that they are unable to access the web site via http://68.5.129.61:81/ion/. Troubleshooting found that site does not have a fixed IP address. The New IP address is http://68.4.75.33:81/ion/. The ISP (Cox Communications) is contacted and a plan is developed to set the site up with a fixed IP Address. As part of this plan, the site will also have a Domain Name through Network Solutions. The Domain Name assigned is **dgmonitors.com.** In January, access to the site will be by use of the Domain Name.
11/14/02	**Sunnyvale Site** – PG&E installs the ION 8500 equipment for the PCC. The monitor is placed in operational but the DSL equipment is not available so the monitors cannot be configured and is not communicating with the web server.
11/22/02	**South Gate Site** – Communications is lost. Reflective makes a site visit to troubleshoot DSL and communication problem. The wiring checkout and both the DSL & monitors is re-booted which resolves the problem.
11/27/02	**Redlands Site** – Communications is lost. PM makes a site visit to troubleshoot the problem. As part of the troubleshooting, a monitor configuration error was corrected and the communication card was replaced. During troubleshooting, it as discovered that the shorting links were found closed. The shorting links were open and the monitors returned to service.
11/29/02	**Web Server** – Daily checks by Reflective of the web server finds that the backup routine is not running. PM via pcanywhere logs onto web server and re-configures the backup scheduler.
12/19/02	**Availability, SARFI & SATHD Report** - PM submits to Reflective special reports for Availability, SARFI & SATHD to augment the standard Power Quality reports in the ION Report Generator. These reports will be used to analyze the data and included in the Quarterly and Final Reports.
12/27/02	**Los Angels Site** – Reflective receives & reviews LADWP drawings for DG Skid with the New Fuel Cell. Delivery of the new Fuel Cell was schedule for end of December with installation in January 2003. Monitor installation is scheduled for February.
1/5/03	**4th Quarterly Report** – Complete & issue Quarterly Report. Issue reports to program participants.

	South Gate Site – Site owner request specific data to analyze performance of the PV system. Analysis indicates that system is not producing at rated output. Based on this analysis, owner changes orientation of solar cells with an increase in output.
1/8/03	**Website** – Data files and reports are converted to PDF format and the web pages are updated to include these new PDF files along with the 4th Quarter results. **Internet Service Provider (ISP)** – Due to comments received from program participants, efforts are initiated to speed up the web site. Cox Communications updates web site to Business Services with new Modem and 128Kbps Downstream and Upstream speeds. Cable from the street to the house is replaced to reduce line loss and increase signal strength. Router and Port 80 problem investigation and a new Cisco PIX Firewall router selected and obtained. Setup Domain Name for web site (dgmonitors.com). Process application for fixed IP address with Cox Communications. **Irvine, South Gate & Redlands Sites** – PCC communication (Ethergate Lockup) is lost 1/8/03. Reflective makes site visits 1/9/03 to perform troubleshooting and re-boots Ethergate monitor to clear problem and reestablished communication.
1/15/03 – 4/28/03	**Sunnyvale Site** – PM installs the ION 7600 equipment for the DG and the wireless Ethernet system to provide communications between the DG monitor and the PCC monitor. The monitors and Ethernet system is placed in operational but a problem with the DSL surface. Pac Bell (SBC) indicated that a DSL line is incompatible with the High Voltage Protection (HVP) provided by Optical Isolators in the PG&E Metering cubicle where the PCC meter is installed. Different communication options are review by both Reflective and PM. A solution is developed and presented to site owner and the existing internal line to the DG monitor will be converted to DSL. The owner orders this DSL service. PM makes a site visit 4/28/03 setup and configures the monitors and Ethernet system. Reflective modifies the framework and completes web site setup. **Irvine Site** – PCC communication (Ethergate Lockup) is lost 1/14/03. Reflective makes site visits 1/24/03 to perform troubleshooting and reboots Ethergate monitor to clear problem and re-established communication.
1/28/03 – 2/8/03	**San Diego Site** – PM installs the ION 7600 equipment for the PCC and DG. The monitors are placed in operational 1/20/03. At this site, the two NGIC run during the day and one is secured at night. On 1/25/03, Reflective makes a site visit to program the monitors, setup network parameters and activate DSL communications with the web server. I problem with the IP and Gateway address is encountered. Troubleshooting this address problem with Real Energy does not resolve this issue. PM makes an additional site visits on 2/1/03 and 2/8/03 and sets the proper IP and Gateway address. Reflective completes monitor programming and setup of web site.
2/1/03	**Reports & Website** - Developed the Monthly Report and update web site to include January data (Load Profile, Monitor Availability, Power Quality, SARFI & SATHD).
2/20/03 –	**Website –** Cisco PIX 501 Firewall Router is received but initial

4/13/03	programming by Reflective fails. PM (PM) attempts to program the router on 3/7 but this endeavor also fails. PM takes the router to their facilities, programs the router and performs final configuration on 4/13.
2/25/03 – 4/4/03	**Los Angeles Site**– An additional Site Survey with Owner, Reflective and PM based on installation of new Fuel Cell. Revised plan for monitor installation developed with Owner installing the monitors under supervision of PM. Monitors are installed 3/25/03 to 4/4/03.
2/28/03	**Internet Service Provider (ISP)** – The Hybrid Fiber Coax connection for the Internet service to the web site is upgraded from 128K Symmetrical to 384K Symmetrical to improve access, navigation and speed.
3/1/03	**Reports & Website** - Developed the Monthly Report and update web site to include February data (Load Profile, Monitor Availability, Power Quality, SARFI & SATHD).
3/2/03 – 4/19/03	**South Gate Site** – Intermittent communication problems 3/2/03 becomes total loss of communication. Reflective troubleshooting is unable to resolve problem. Site troubleshooting the first week of March by PM restores communication for a few days but site drops off-line by weekend. Additional troubleshooting by Reflective restores communications by rebooting the DSL Modem and both monitors and then "pinging" out from the Ethergate monitor. Reflective explores the possibility of monitor firmware upgrade with PM to improve the Ethergate Communication (PC Lockup). PM makes a site visit 3/13/03 and fells that the problem is a MAC address problem. Reflective contacts Verizon 3/14/03. Verizon performs a communication test and re-builds the circuit. They confirm that IP and MAC Addresses are correct. Reflective replaces DSL Modem 4/19/03 reboots both monitors and communications is restored.
3/6/03	**Irvine Site** – PCC communication is lost 3/6/03. Reflective makes site visits to perform troubleshooting. Problem isolated to monitor communication card and it was rebooted to restore communication. PM investigating possible methods of resolving this issue and is developing firmware upgrade.
4/4/03	**Reports & Website** - Developed the Monthly Report and update web site to include March data (Load Profile, Monitor Availability, Power Quality, SARFI & SATHD). **Irvine Site** – Reflective works with PM (Victoria) and new Beta Firmware is installed in the DG monitor to resolve the PCC communication (Ethergate Lockup) problem. Reflective makes site visits 4/9/03 to complete the installation and setup and communication is restored. PCC communications is lost again and Reflective makes an additional site visit 4/25 and re-boots DG monitor to restore communications. PM looks into other Firmware modifications to correct this problem and installs another version of the Firmware.
4/8/03	**1st Quarterly Report** – Complete & issue Quarterly Report. Issue reports to program participants.
4/23/03 – 6/23/03	**Los Angeles Site**– DSL Modem is installed and Reflective configures monitors and places them in operational 4/23/03. Reflective then setup network parameters and activate DSL communications with the web server. Analysis of the data indicates that a problem exists with the wiring of the monitors because the power appears to be revised. Several site visits are

	required by Reflective and PM and finally on 6/23/03 the monitor wiring is modified from Wye to Delta and this correct the issue.
4/25/03	**San Diego Site** – – PCC communication (Ethergate Lockup) is lost 4/15/03. Reflective makes site visits to perform troubleshooting and reboots Ethergate monitor to clear problem and re-established communication.
5/1/03	**Reports & Website** - Developed the Monthly Report and update web site to include April data (Load Profile, Monitor Availability, Power Quality, SARFI & SATHD).
5/27/03	**San Diego Site** – – PCC communication (Ethergate Lockup) is lost 5/15/03. Reflective makes site visits to perform troubleshooting and reboots Ethergate monitor to clear problem and re-established communication.
5/28/03	**Irvine, Los Angeles, Redlands & San Diego Sites** – PM upgrades Ethergate Monitor Firmware at each of these sites with version V239 to resolve the Ethergate Lockup problem. This Firmware requires Reflective to reinstall the program specific change in the web server ION Enterprise Web Reach Node Diagram for each monitor. This change causes a reset in the Mo Stats Node Diagram for each monitor.
6/1/03	**Reports & Website** - Developed the Monthly Report and update web site to include May data (Load Profile, Monitor Availability, Power Quality, SARFI & SATHD).
7/1/03	**Reports & Website** - Developed the Monthly Report and update web site to include June data (Load Profile, Monitor Availability, Power Quality, SARFI & SATHD). Develop special reports for the Los Angeles site based on Owner request.
7/2/03 – 7/23/03	**2nd Quarterly Report** – Complete & issue Quarterly Report. Issue reports to program participants.
7/13/03 – 7/30/03	**Irvine Site** – PCC communication (Ethergate Lockup) is lost 7/13. Reflective makes site visits to perform troubleshooting. Reboot monitors and DSL Modem does not restore communication on 7/24. SBC technical support checks DSL line, modem and address and does not find any problems. Additional troubleshooting on 7/29 found a problem with the DSL line and SBC troubleshooting found a disconnected wire at the communication hub. Communications is restored on 7/29.
7/27/03	**San Diego Site** – PCC communication (Ethergate Lockup) is lost 7/27 and PM was able to remotely re-boot the monitor restoring communications.
7/30/03	**Sunnyvale Site** – Sunnyvale NGIC Monitor Framework is re-configured to provide power data in 15-minute intervals instead of the existing 6-hour interval.
8/1/03 – 8/8/03	**Reports & Website** - Developed the Monthly Report and update web site to include July data (Load Profile, Monitor Availability, Power Quality, SARFI & SATHD)..
8/10/03 – 9/8/03	**Web Server** – The web site (dgmonitors.com) server is moved from San Clemente to Laughlin. On 8/10, the web site was disconnected from the Cox ISP and on 8/13, Power Measurement (Victoria) support modification to the server for setup of CMA ISP. On 8/14 Network Solutions is contacted to update the web mapping to the new site IP and DNS address. The process is expected to take approximately 72 hours but after the require interval the mapping is still to the Cox ISP. CMA is contacted and a problem exists with the MAC address. In the interim, the site can be access by the IP

	address (http://65.244.211.245/). On 9/8, the address mapping is corrected and the site is back on-line.
8/1/02 – 9/10/03	**Redlands, San Diego & South Gate Site -** Redlands, San Diego & South Gate sites loss communication 8/18. o On 8/19, **Redlands** recovered on its own o On 8/29, **San Diego** is remotely rebooted by PM o On 9/5, **South Gate** had new firmware installed by PM and the monitor is re-configured on 9/10.
8/26/03 – 10/6/03	**Database Manager** - Database Manager backup routine stops and troubleshooting by Reflective is unable to re-start the backup service. PM investigates and is unable to detect a problem with the Database Manager configuration. On 9/30, PM recommends deletion of the Beta version of the software and reload with the current revision (ver 3.1.0). Reflective reloads Database Manager 10/6 and the Backup and Archive service is restored
8/30/03 – 9/4/03	**Los Angeles Site** – PCC, FC, NGMT2 & NGMT3 communication (Ethergate Lockup) is lost 8/30 and investigation found no anomalies. Site recovered on its own 9/4.
9/1/03	**Reports & Website** - Developed the Monthly Report and update web site to include August data (Load Profile, Monitor Availability, Power Quality, SARFI & SATHD)..
9/17/03 – 10/31/03	**South Gate Site** – South Gate communications is loss 9/17 and unable to re-establish via the network server. Site troubleshooting 9/28 finds no problem with monitor, DSL and associated wiring. Contact with Verizon finds that a billing issue has resulted in the service being disconnected. Reflective takes the steps necessary to correct the situation. Reflective makes two site visits (10/12 & 10/31) to restore service but communications is intermittent.
9/30/03	**Redlands Site** – The permit process at Redlands is complete and installation of the Capstone Microturbines and construction is schedule to start within the next 30 days.
10/3/03	**Reports & Website** - Developed the Monthly Report and update web site to include September data (Load Profile, Monitor Availability, Power Quality, SARFI & SATHD)..
10/6/03 – 10/26/03	**Los Angeles Site** – PCC, FC, NGMT2 & NGMT3 communication (Ethergate Lockup) is lost 10/6 and PM performs a remote re-boot 10/26 and communications is restored.
10/4/03 – 10/15/03	**3rd Quarterly Report** – Complete & issue Quarterly Report. Issue reports to program participants.
10/21/03 – 10/26/03	**Irvine Site** – PCC communication (Ethergate Lockup) is lost 10/21 and PM was able to remotely re-boot 10/26 the monitor restoring communications.
10/21/03 – 10/26/03	**San Diego Site** – PCC communication (Ethergate Lockup) is lost 10/21 and PM was able to remotely re-boot 11/2 the monitor restoring communications.
10/26/03 – 10/31/03	**South Gate Site** – Communication is lost 10/26 to both the PCC and PV Monitors. Verizon is contacted and they install a filter and line splitter. A site visit 10/31 restores communications.
10/3/03 – 11/08/03	**Los Angeles Site** –The Los Angeles site has a lighting strike, which trips the Fuel Cell, but NGMT1 continues to operate. NGMT1 starts recording Transients events and by the end of the month a total of 7635 is entered

	into the database. By 11/3 at 11 pm, a total of 2,385,508 Transient events is entered into the database as recorded by the Mo Stats" counter. The Waveform & Transient capture is turned off 11/04. The Fuel Cell is returned to service 11/6 and the Waveform & Transient capture is reactivated 11/08 @ 10 pm.
11/1/03	**Reports & Website** - Developed the Monthly Report and update web site to include October data (Load Profile, Monitor Availability, Power Quality, SARFI & SATHD)..
11/08/03 – 11/13/03	**Irvine Site** – PCC communication (Ethergate Lockup) is lost 11/08 and PM was able to remotely re-boot 11/13 the monitor restoring communications.
11/18/03	**Reports & Website** - Developed the Monthly Report for December.
11/26/03 – 12/18/03	**Irvine Site** – PCC communication (Ethergate Lockup) is lost 11/26 and PM (Victoria) was able to remotely re-boot 12/18 the monitor restoring communications.
12/05/03 – 01/07/04	**Internet Service Provider (ISP)** – CMA, which was the Internet Service Provider (ISP) for the dgmonitors web site, changes Static IP address 12/5/03. Site went off-line and Reflective changed the ISP. Sprint DSL service is contracted 12/18/03 with installation on 1/6/2004. Web site is restored on 1/7/04.
12/18/03	**Website** - Developed the ION Reports and update web site to include November data (Load Profile, Monitor Availability, Power Quality, SARFI & SATHD). Because of the large quantity of Transient events recorded by the Los Angeles Site NGMT1 in November, the Power Quality reports has to be generated in two hour increments instead of the monthly increment. The reason why problems were encounter with the report generation was due to the waveforms were over written when the 14000 transients occurred in the 4-hour period. By default he depth of the transient waveform recorder in the 7600s and 8500s is 50. With that quantity of transient, they were occurring on average every 0.97 seconds. During that period the meter was processing an overwriting these waveform samples before they could be downloaded into the database. Unfortunately Excel has some limitations of it's own when it comes to processing large data arrays. The results of the two-hour increments is then combined manually and then linked to the web site. **ION Report Generator** – When the November reports are generated, a discrepancy in Transient events for Los Angeles is discovered. The number of Transient events recorded by the PQ report (INCIDENT Report 134355) for Los Angeles NGMT1 was 215,534 while the Mo Stats count was 3,270,859. This discrepancy is forwarded to PM who investigates and comes to the following conclusion. 1. The PQ report bases its' information on the number of events recorded by the meter. If the number of transients is occurring faster than the information can be downloaded or the number of events is occurring too often and too quickly the meter will not be able to capture all of the events. The custom framework (Mo Stats) that was created for this project does not have to worry about try to record ever event or the waveforms. This framework just counts the number of events based on the number of times the pulse output on the transient module has been triggered. Therefore, it is more likely to represent the

	true amount of actual transient events. 2. By default, the PQ report group's events that occur within a certain time period together and counts that as only one event. This is done so that memory resources on customer PCs are not overloaded. If memory requirements to generate a report are more than the PC can handle Excel will not finish generating the report and it will freeze or crash. Either way, the Mo Stats count will be the more accurate figure to use, assuming that the counter reset properly at the beginning of each month.
12/29/03 – 3/1/04	**ION Report Generator** – During the development of the monthly reports, it is discovered that a problem exists with the SARFI report, which PM developed for Reflective for monitoring project analysis of the Power Quality data. It appears that all Sag & Swell events no matter what the magnitude is recorded as $SARFI_{90}$. PM Victoria is contacted (INCIDENT Report 127922) and the report calculations and generation is under investigation.
1/1/04 – 1/2/04	**Reports & Website** - Developed the Monthly Report and update web site to include December data (Load Profile, Monitor Availability, Power Quality, SARFI & SATHD).
1/16/04 – 1/23/04	**4th Quarterly Report** – Developed Quarterly Report and submitted for review. **Reports & Website** – Developed additional ION Reports and convert to "PDF" files and update web site.
1/20/04 – 1/31/04	**Database Manager** – During checks of the web site it is discovered that the daily backup folders are generated but no files are being entered into the folders. PM Victoria is contacted (INCIDENT Report 136827) and indicates that the software version that Reflective is using has some limitations and the ' daily incremented backup' functionality is not well developed. They are not planning on improving on the software in this area in the foreseeable future and recommend setting the software to only use full backups. The Database Manager setting is changed and full backups is activated and operational.
1/22/04 – 1/30/04	**Irvine Site** – Fuel Cell communication is lost 01/22. PM is contacted to reboot the monitor remotely but prior to the remote reboot communications is re-established on 1/30/04. **San Diego** – NGIC communication is lost 01/22 and PM. PM is contacted to reboot the monitor remotely but prior to the remote reboot communications is re-established on 1/30/04.
1/22/04 – 2/4/04	**Redlands** – Site goes off line and an initial assumption for loss of communication is the installation of Capstones Microturbines. Local maintenance crew reboots monitors and DSL modem but communications remains loss. A site visit by Reflective resolves the Ethergate lockup problems. Installation of the Capstones Microturbines has been delay due to a discrepancy with the fence location. Modification of the plans and permits has to be made and approved prior to start of installation.
2/1/04 to 2/2/04	**Reports & Website** - Developed the Monthly Report and update web site to include January data (Load Profile, Monitor Availability, Power Quality,

	SARFI & SATHD).
2/12/04 – 2/18/04	**Los Angeles Site** – PCC communication (Ethergate Lockup) is lost 02/12 and local maintenance was able to re-boot the monitor restoring communications.
2/13/04 – 2/24/04	**San Diego Site** – PCC communication (Ethergate Lockup) is lost 02/13 and Server Re-boot by Reflective was able to restore communications. **Redlands Site** – PCC communication (Ethergate Lockup) is lost 02/13 and Server Re-boot by Reflective was able to restore communications.
2/24/04 – 2/29/04	**Reports & Website** – Developed additional ION Reports and convert to "PDF" files and update web site.
3/1/04 – 3/2/04	**Reports & Website** - Developed the Monthly Report and update web site to include February data (Load Profile, Monitor Availability, Power Quality, SARFI & SATHD).
3/1/04 – 3/12/04	**ION Report Generator** – Develop a manual SARFI Report for September 2003 for evaluation by PM Victoria. After considerable debate about the calculation used in the development of the report, PM position is that the report meet the initial report specification. Several other recommendations were made by Reflective, which correct the report, but these were rejected by PM. Since this problem could not be resolved, Reflective developed alternate methods to generate the report manually from the Power Quality Report.
3/1/04 – 3/12/04	**ION Report Generator** – Develop a manual SARFI Report for September 2003 for evaluation by PM Victoria. After considerable debate about the calculation used in the development of the report, PM position is that the report meet the initial report specification. Several other recommendations were made by Reflective, which correct the report, but these were rejected by PM. Since this problem could not be resolved, Reflective developed alternate methods to generate the report manually from the Power Quality Report. **Web Server** – Reflective Energies upgrades Server memory from 512 KB to 1.5 GB to improve analysis of the data for the final report. A new internal 120 GB hard drive is order for additional storage of database files and reports.
3/31/04	**Final Report –** Meeting with Cris Cooley & Joe Simpson to review the status of the final report. Determine methods of resolving issue with 1) data collection, 2) data preparation, 3) data analysis and 4) what steps are required to issue the report.
3/31/04 – 4/2/04	**Flicker Report** – As a result of the final report meeting and the review of the data collection and analysis, it was noted that the ION Flicker report could not be generated for the Sunnyvale PCC monitor in the same format as the rest of the sites. The Sunnyvale PCC monitor is the only ION 8500 in the program. All of the rest of the meters are ION 7600. PM was contacted and ***Incident 144441*** was generated to track this issue. Basically, their response was that the Data Recorder Modules don't exist in the 8500 meter except the ones for Flicker. So to obtain a Flicker report we will need all the data recorders as in EN50160_General & EN50160_Summary report. The 8500 does not have the same features as

	the 7600 because it's designed for used in North America (the round feature). The 8500 could be capable of handling this feature if the Monitor framework is reprogrammed and then Vista reprogram to include EN50160. Based on the amount of effort required to implement this reprogramming, Reflective Energies does not plan to incorporate this feature in the ION 8500.
4/1/04 – 4/2/04	**Reports & Website** - Developed the Monthly Report and update web site to include March data (Load Profile, Monitor Availability, Power Quality, SARFI & SATHD).
4/5/04 – 4/6/04	**1st Quarterly Report** – Developed Quarterly Report and submitted for review.
4/6/04 – 4/13/04	**Archive Database** – During the development of the Final Report, some additional ION Reports were required for Total Harmonic Distortion. To generate these reports, use of the Archive Database was required. It was found when the first quarter 2003 THD report was created that Archive file actually starts 1/12 not 1/1. Power Measurements ***Incident 145224*** was open. Another Archive file was available and overlaps this date. What is required is the ability to append one Archive file to another and then eliminate the duplicate records? Power Measurements response was that once the databases are Archived the structure and form of the archive is static and cannot be changed. Unfortunately there is no way to append these two files. PM recommended that Reflective Energies create 2 separate reports to cover the different time periods. This approach will not work for THD and an alternate method which uses monthly data instead of quarterly data will be used.
4/6/04 – 4/21/04	**Power Quality Report (EN50160)** – One of the ION Reports which provides Power Quality analysis is the EN50160. One of the items included in this report is Voltage Unbalance. Since one of the monitoring sites failed this criteria. An attempt was made to determine how this was determined as a means to understand and troubleshoot this problem. Power Measurements ***Incident 145971*** was open and a detail description was provided along specific details about the Signal Limit Evaluation Module.
4/21/04 – 6/10/04	**Final Report –** Cris Cooley TA SARFI analysis is reviewed and correlated with Joe Simpson's analysis and the results is incorporated into the draft report. The draft is sent to Cris Cooley, Dough Dawson and Edan Prabhu for review. Draft comments are received and incorporated and the final is sent to Edan Prabhu.
5/1/04 – 5/2/04	**Reports & Website** - Developed the Monthly Report and update web site to include April data (Load Profile, Monitor Availability, Power Quality, SARFI & SATHD).
5/24/04 – 5/25/04	**ION Report Generator** – The MS Office software on the Webserver was updated to MS Office 20-03 Professional and when an attempt was made to generate some ION Reports PQ reports the process failed with a error code indicating that a "Programmatic access Visual Basic Project is not trusted" ***Incident 149569*** report was issued and Power Measurement responded the next day with the procedure for Excel setup which resolved this issue.
5/31/04 – 6/7/04	**Redlands Site** – PCC communication (Ethergate Lockup) is lost 5/31 and Server Re-boot by site Maintenance Personnel is able to restore communications on 6/7.
6/1/04 – 6/2/04	**Reports & Website** - Developed the Monthly Report and update web site

	to include May data (Load Profile, Monitor Availability, Power Quality, SARFI & SATHD).
6/08/04 – 6/11/04	**Final Report –** Edan Prabhu's comments are reviewed and incorporated into the Final Report. The report is also updated to reflect the new San Francisco PV site. Website is updated to include place holder for the new site as well as a simplified one-line diagram.
6/11/04 – 8/9/04	**ION Report Generator** – The EN50160 report is use mainly for the flicker and the current report generated had "**No Data"** in the **Harmonic Voltage** column. Other quests also surfaced for **Supply Voltage Unbalance** and the trigger set point while **Supply Voltage Dips, Short and Long Interruption, Temporary Overvoltages** just had a "-" in their columns. ***Incident 151444*** report was issued and Power Measurement responded the next day with the procedure for Excel setup which resolved this issue.
6/14/04	**San Francisco Site Survey -** Complete the site survey of the Moscone Convention Center site in San Francisco and develop an implementation plan for monitoring the 675 kW PV system.
6/22/04	**Final Report Presentation –** Delivered a briefing at the Rule 21 Meeting in San Diego which summarizes the final monitoring report. Then updated the website to include the briefing under the Program Documentation Section.
6/21/04 – 6/29/04	**Redlands Site** – Site communication is lost 6/21 to both the NGMT & PCC monitor and re-boot of both the DSL Modem and Monitors by site Maintenance Personnel is able to restore communications on 6/22, 6/24 &/26/29. Total loss of communications on 6/27 could not be corrected by site personnel and Reflective Energies made a site visit. The problem was isolated to the DSL service. Reflective Energies was able to restore communication but the long term resolution will require a change in DSL service.
71/04 – 7/2/04	**Reports & Website** - Developed the Monthly Report and update web site to include June data (Load Profile, Monitor Availability, Power Quality, SARFI & SATHD).
7/3/04	**2nd Quarterly Report** – Developed Quarterly Report and submitted for review.
7/17/04 – 7/27/04	**Sunnyvale Site** – PCC communication (Ethergate Lockup) is lost 7/17 and Server Re-boot by site Maintenance Personnel is unable to restore communications and site personnel checks monitors, DSL modem and wireless bridge on 7/27. Nothing out of the ordinary was found but communications is restored.
7/16/04 – 7/27/04	**Website** – On 7/16 a power outage causes the Website to go down and on restoration of the power the site starts but unable to complete boot sequence. This was due to the fact the Joe Simpson was on vacation and unable to complete the sign-in and password. This was accomplished 7/27 and the site was restored. Data check of all sites finds no loss of data during the period the server was off-line.
7/26/04	**Final Report -** The Commission approves the draft Final Monitoring Report and it is converted to PDF and posted on the website with a direct link of http://www.dgmonitors.com/FinalRPT/MonitoringFinal-v5d.pdf
8/1 TO 8/2	**Reports & Website** - Developed the Monthly Report and update web site

	to include July data (Load Profile, Monitor Availability, Power Quality, SARFI & SATHD).
8/4/04	**Redlands Site** – Notification by site personnel requires a trip to check the CT installation prior to termination of DG power feeders. Power Measurements also attends but Shaw Electric only pulls the cable but does not install breaker or terminate feeders. Installation of the DG pad and Capstones was completed. Arrangement s is made to have Shaw Electric slip the CT's over the feeder cables during the outage 8/25. Due to an oversight in notification of SCE, the outage is re-scheduled for the first week of September.
8/17 to 8/26	**South Gate -** Site communication was lost 8/17 to both the NGMT & PCC monitor and troubleshooting from the Web Server was unable to re-establish communication. Verizon was contact and working with site personnel the DSL modem was re-booted but this did not correct the problem and Verizon send a technician on 8/25. At this point, everything was checked from the modem into the Internet but the web server was still unable to communicate with the monitors. Reflective Energies performed site troubleshooting and re-established communication 8/26 but found that the panel lock had been cutoff. This may explain the high number of sags (56) which occurred in May 2004 at this site while the normal monthly total sags was in the 0 to 6 range.
8/14	**Plumas Sierra Rural Cooperative** – Based on recommendation by Linda Kelly, Bob Marshal of Plumas Sierra Rural Cooperative was contacted in an effort to explore the possibility of monitoring DG being installed a correction and water facility near Sussanvile. Based on the present status of these projects and contract negotiation with the state, it appears that installation can not be defined at this time.
8/17	**San Francisco Site** – An installation plan was developed and submitted to SFPUC which will require an outage to install new CT's on the 4160 Feeders to Substation C. This plan will be presented to the Moscone Center by SFPUC in September.
8/25	**San Diego Induction Site** - In our search for an Inductive DG Site, we evaluated two sites in San Diego. One site (Merrill Lynch Building) at 701 B Street was our prime candidate (4 monitors required) but is down due to a chiller failure with no schedule return to service date at this time. As a result, we have selected our backup site at 9275 Skypark. This site has two individual buildings each with a Hess 200 Inductive Microgen (4 monitors required). A proposal from Power Measurements is expected the first week of September.
8/31	**Premium Plus Support** – Reflective Energies upgraded its support agreement with Power Measurements. As part of this package, our version of ION Enterprise (4.5) will be upgraded to 5.0 in September. This package also includes upgrade to the VIP configuration and conversion of the Sybase database to SQL file.
9/1/04 TO 9/2/04	**Reports & Website** - Developed the Monthly Report and update web site to include August data (Load Profile, Monitor Availability, Power Quality, SARFI & SATHD).
9/6/04 to 9/10/04	**Redlands Site** – PCC communication (Ethergate Lockup) is lost 9/6 and Server Re-boot by Reflective was unable to restore communications. Site

	maintenance personnel re-booted both the DSL Modem and Monitors which restores communication.
9/13/04	**San Diego Induction Site** – In our search for an Inductive DG Site, Reflective Energies evaluated two sites in San Diego. One site (Merrill Lynch Building) at 701 B Street was the prime candidate requiring four monitors but it was down due to a chiller failure with not schedule return-to-service date. As a result, our backup site (Arden Management Complex) at 9275 & 9325 Skypark is selected. Both sites are fed from SDG&E Kearny Substation Circuit 251 which is a 12 kV radial Feeder. 9275 Skypark Ct. is internally identified by SDG&E as DG#503 while 9325 Skypark Ct. is identified as DG#483.
9/17/04 to 9/27/04	**San Diego Synchronous Site** – Due to communications issues over the last year, the DSL modem was replaced (9/17) by Power Measurements. After some configuration issues with the IP address, communications was re-established 9/27
9/17/04 to 9/29/04	**Final Monitoring Report Comments** – Received comments to the Final Report from SDG&E (Petrina Burnham). Developed a response and incorporate some of the comments and expanded the DG ON/OFF Analsysis.
9/22/04	**Redlands Site** – Reflective Energies attended the commissioning and startup with Shaw Electric and Capstone performing startup. After clean-up of some construction items for the inspector, the procedure went well up to actual startup of the Capstones. Each Capstone tripped and troubleshooting finally found that an internal trip for gas pressure was taking them out. The design avoids pulling a vacuum on the gas line and trip when the gas pressure goes below 2 psi. When the Capstones was ramping up, the monitors did record a negative KW but when the KW went positive, Reflective was unable to switch to phasor diagram in time to see the diagram and verify current phase relationships.
9/30/04	**Premium Plus Support** – The new ION Enterprise version 5.0 was received and schedule for installation by Power Measurements on 9/30 – 10/1. As part of this upgrade, it was planned to convert the database from Sybase to SQL. But the schedule upgrade was postponed until resolution about the database size could be resolved. Due to Server problems, the operating software was upgraded from Windows 2000 Professional to Windows XP Professional.
10/1/04 TO 10/3/04	**Reports & Website** - Developed the Monthly Report and update web site to include September data (Load Profile, Monitor Availability, Power Quality, SARFI & SATHD and new ON/OFF DG Analysis).
10/14/04 to 11/04/04	**Moscone Center PV Site** – Attempts to schedule a second site survey to finalize the propose installation plan and proposal with SFPUC fails and is reschedule for 11/04.
10/20/2004	**ION Enterprise Software -** ION_Inventory and Diagnostic programs were run on the dgmonitors primary ION Enterprise server(s). ION_Inventory created a text file and Diagnostic create a cab file which was sent to Matthew Puscus Power Measurement Technical Support. After these files were analyzed, several items required correction: o No Loopback adapter was setup on dgmonitor server due to operating system upgrade. Working with Power Measurement, the adapter was installed and configured.

	o No ION Enterprise service packs installed. It was recommended that SP3 be installed ASAP but this will have to occur after installation of ION Enterprise version 5.0. o Database file is huge (1.4GB)! It was recommended that it be reduce ASAP. Reduction will be schedule after creation of the October reports. o Operating System configuration includes Windows XP SP2. Power Measurements has not performed any regression testing against SP2. In fact, they are not even using SP2 in office due to several issues introduced according to their IS department. So this SP was uninstalled.
10/17/04 to 10/20/04	**Los Angeles & San Diego Synchronous Site** – PCC communication (Ethergate Lockup) is lost 10/17 and Server Re-boot by Reflective was unable to restore communications. Power Measurements (Matthew Puscus) Technical Support is able to perform a remote re-boot of the Monitors which restores communication on 10/20.
10/22/04	**South Gate Site** – Due to communications issues over the last couple of years, the firmware is upgraded to include a "DSL Keep-Alive" feature. Daniel Jurnove of Power Measurement Technical Support developed new framework programming and the process took three hours with Reflective Energies providing the required start and stop of the ION Enterprise software on dgmonitor server along with reconfiguration on the Monitor. In the process, data for this site was lose for a couple of hours while it was off line.
11/1/04 TO 11/3/04	**Reports & Website** - Developed the Monthly Report and update web site to include October data (Load Profile, Monitor Availability, Power Quality, SARFI & SATHD and new ON/OFF DG Analysis).
11/3/04	**Santa Rosa Site –** Contact Kyle Brocker (Atlas-Pellizzari Electric) and Jay Carpenter (Facility Manager at Santa Rosa Junior College) to investigate a campus site with one 80 kW (Sharp PV System) and two 140 kW Hess Microturbines. Setup it site survey for 11/9.

APPENDIX F: DG MONITORING SITES

Appendix F – DG Monitoring Guidelines

http://www.dgmonitors.com/Doc/Guidelines.pdf

APPENDIX G: MONITORING TEST PLAN

Appendix G – Monitoring Test Plan

http://www.dgmonitors.com/Doc/TestPlan.pdf